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Kawaguchi

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(54) VESSEL PROPULSION APPARATUS

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(30) **Foreign Application Priority Data**

Mar. 9, 2011 (JP) 2011-051668

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B63H 20/14 (2006.01)
B63H 20/20 (2006.01)

(52) **U.S. Cl.**
CPC ***B63H 20/20*** (2013.01)
USPC **440/75**

(58) **Field of Classification Search**
USPC 440/75
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,616,929 B2 * 12/2013 Kawaguchi 440/75

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Kawaguchi, "Vessel Propulsion Apparatus", U.S. Appl. No. 13/402,246, filed Feb. 22, 2012.

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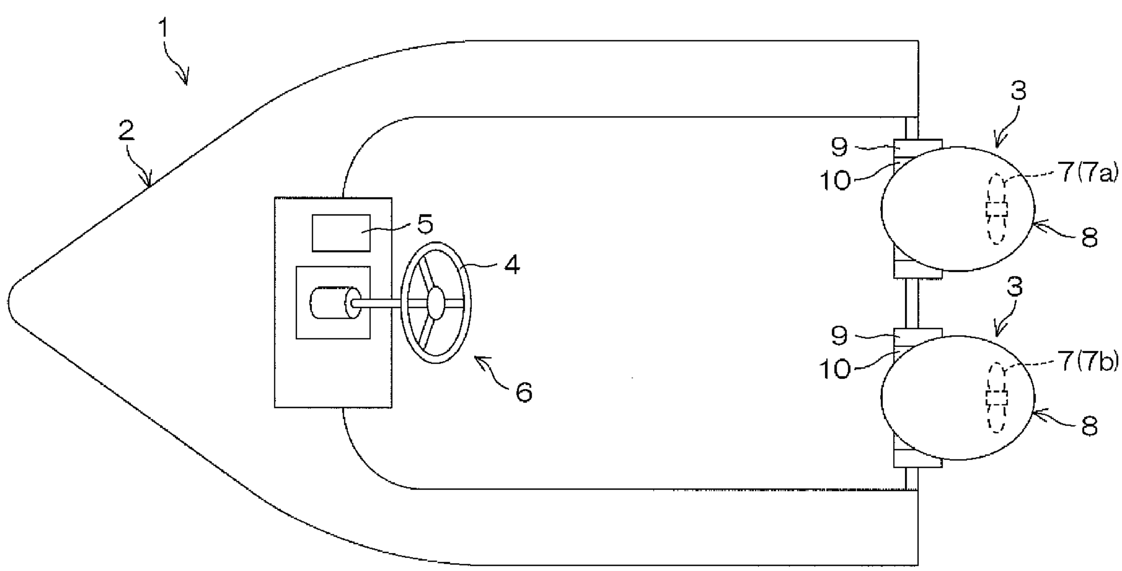
(57) **ABSTRACT**

A vessel propulsion apparatus includes a second shaft that is inserted in a first driven gear and in a second driven gear, that is connected to a dog clutch, and that is arranged to undergo a thrust. The vessel propulsion apparatus includes a first bearing disposed between the first driven gear and the second shaft, a second bearing disposed between the second driven gear and the second shaft, and a case to which a thrust applied to the second shaft is transmitted via the first bearing and the first driven gear or via the second bearing and the second driven gear. The vessel propulsion apparatus includes an adjusting member disposed between the second shaft and at least one of the first driven gear and the second driven gear and arranged to apply a preload onto the first bearing and the second bearing.

8 Claims, 18 Drawing Sheets



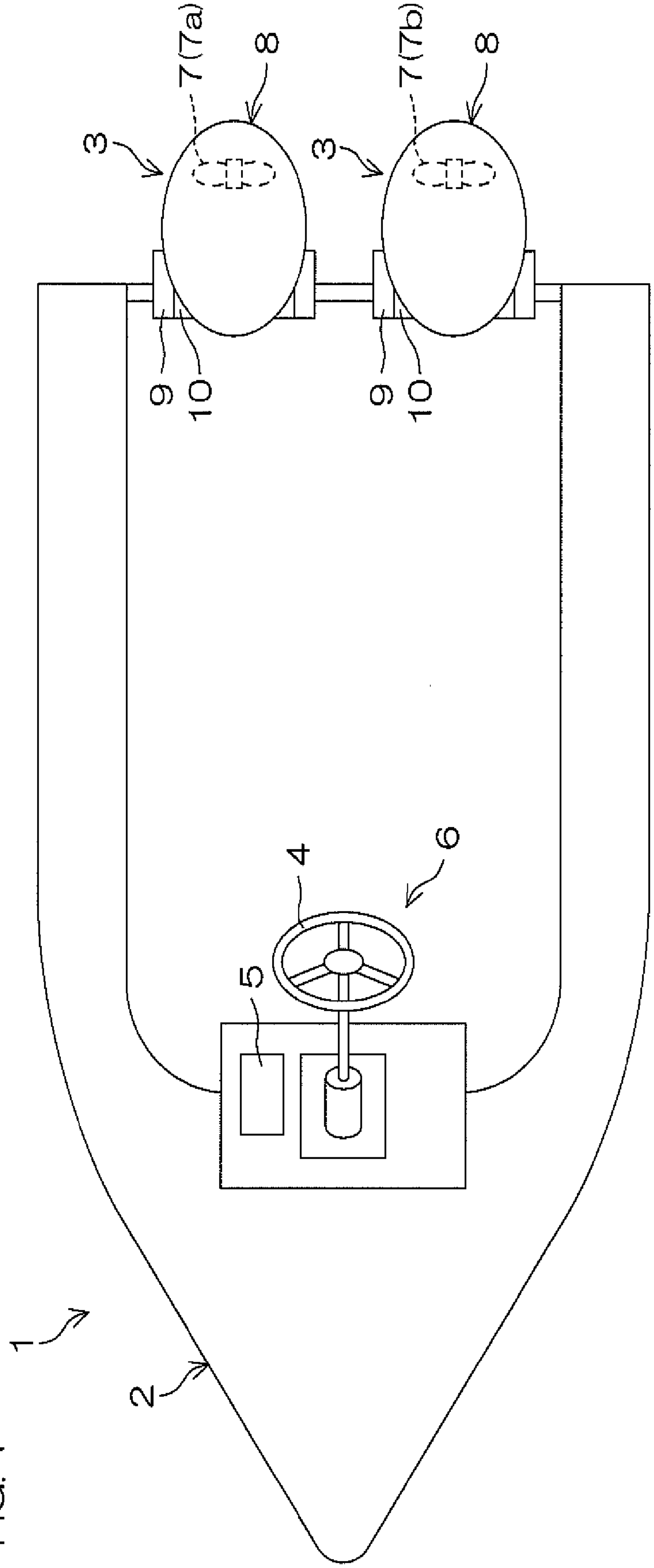
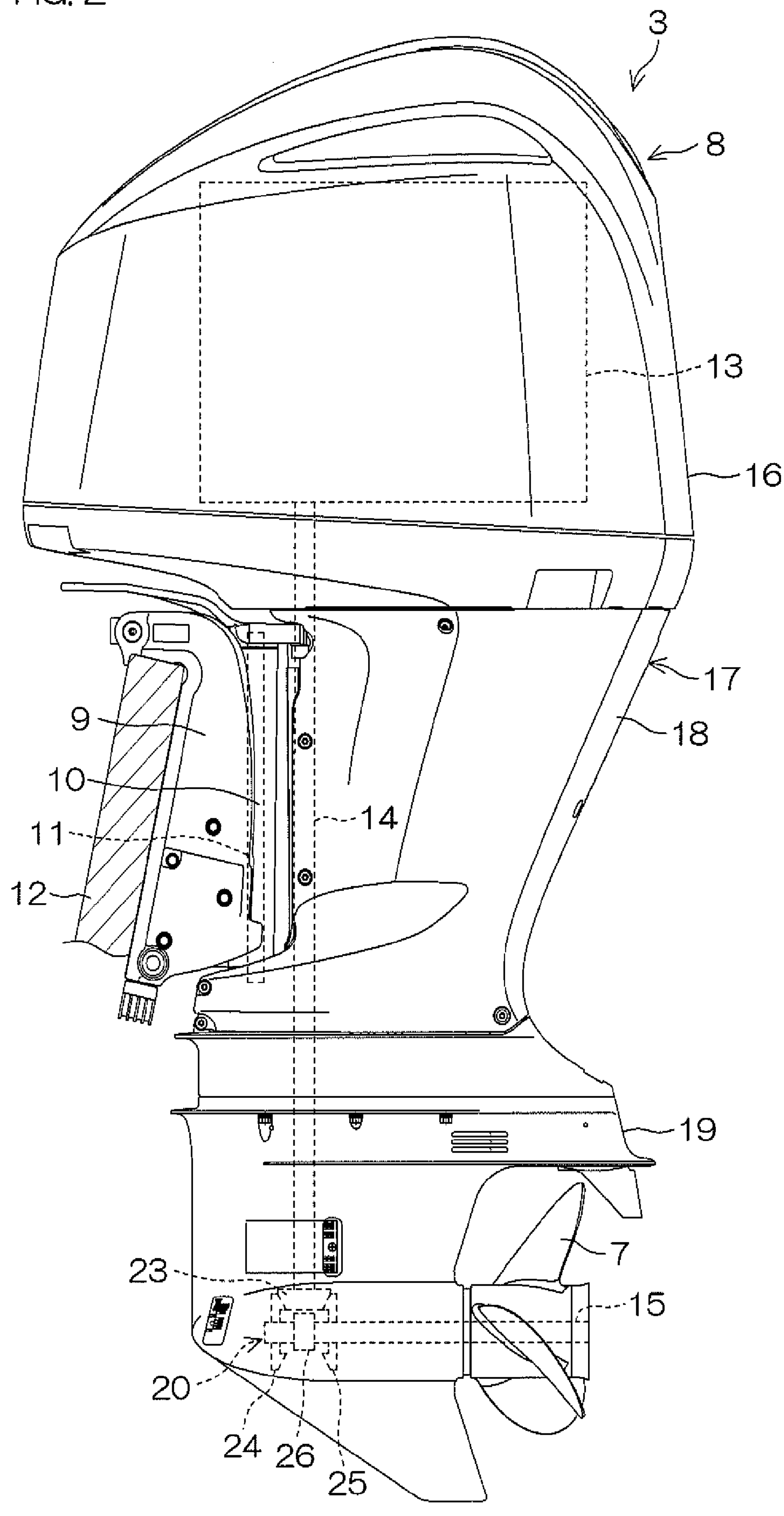


FIG. 1

FIG. 2



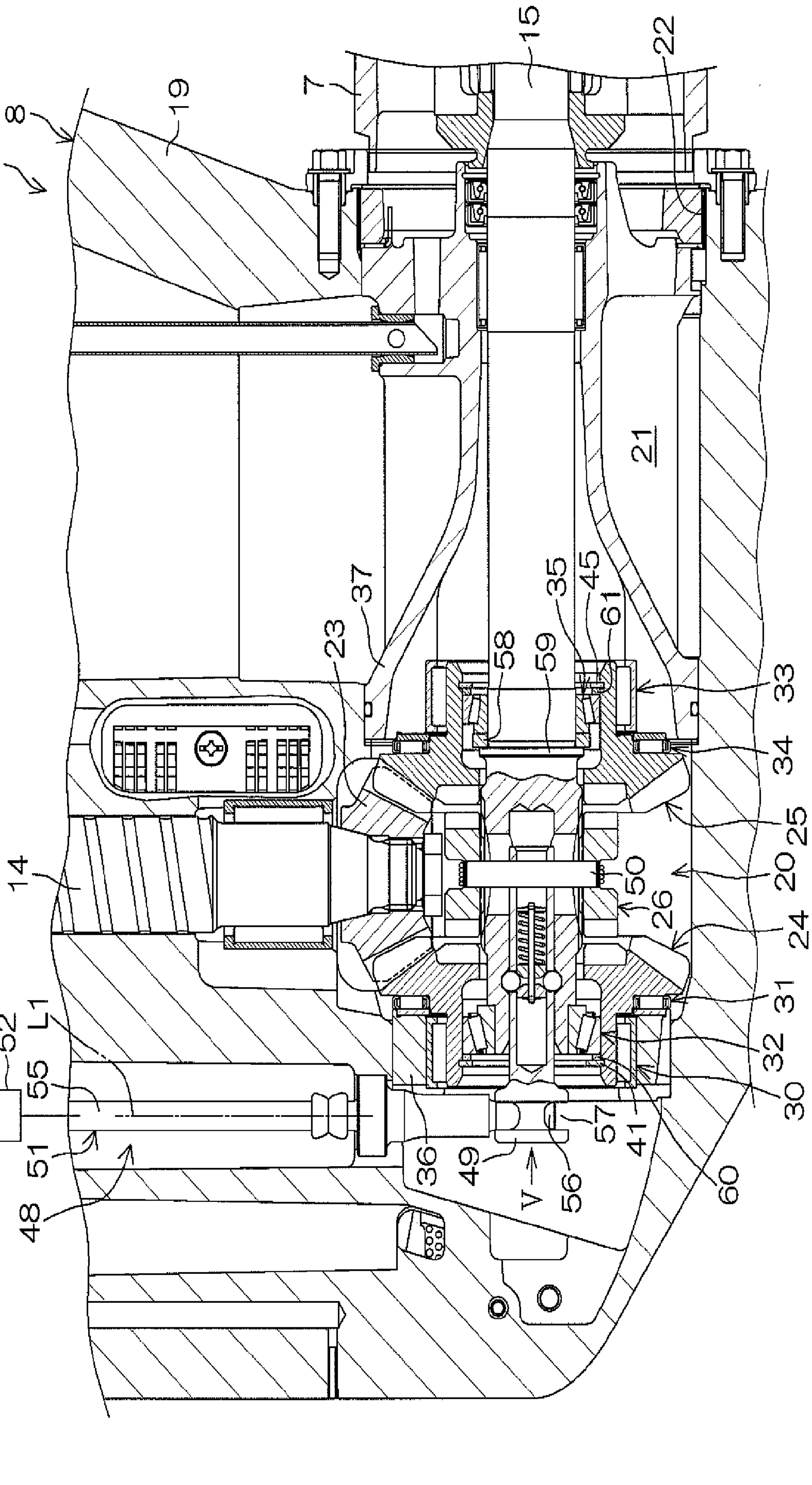

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FIG. 3

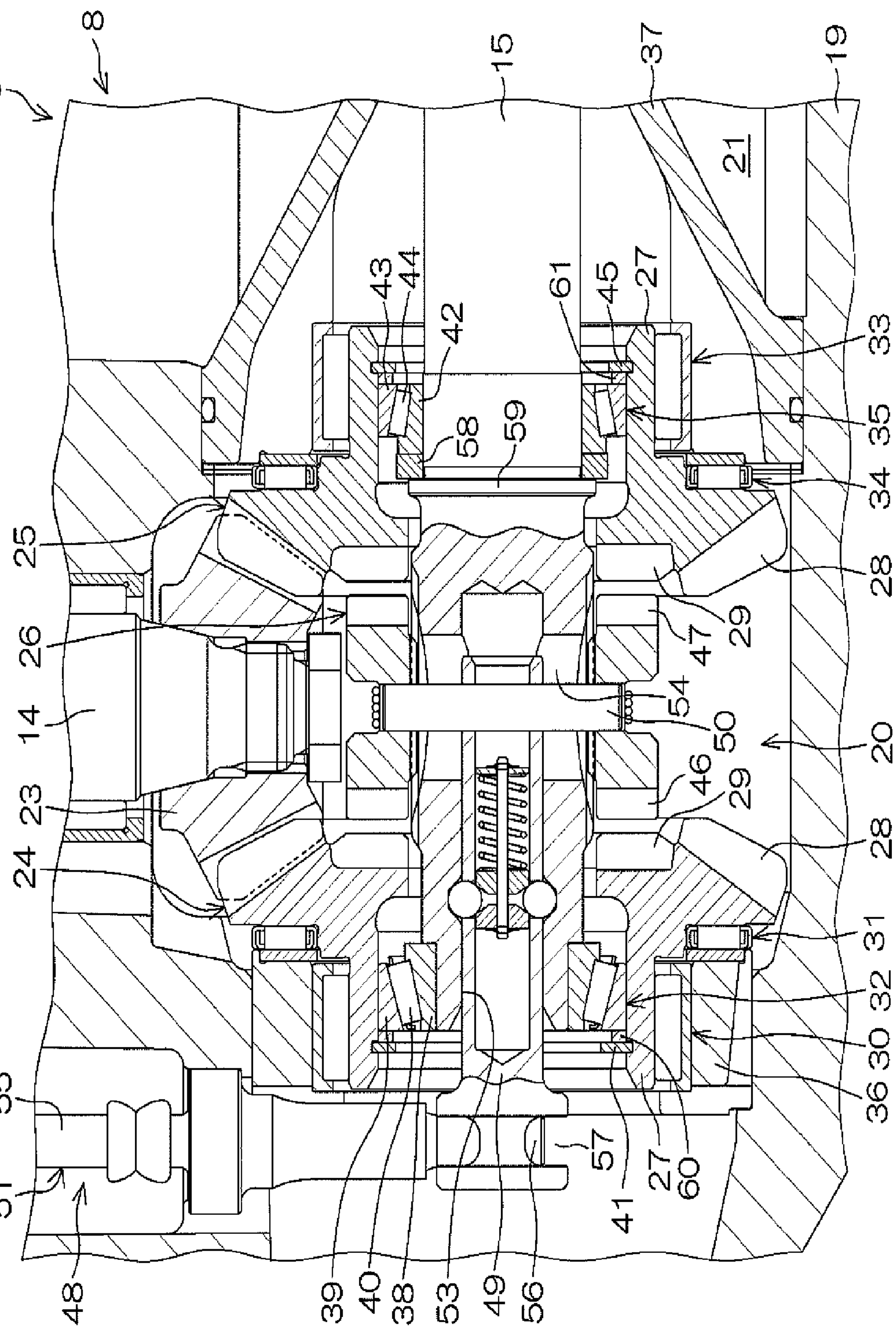
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FIG. 4

FIG. 5

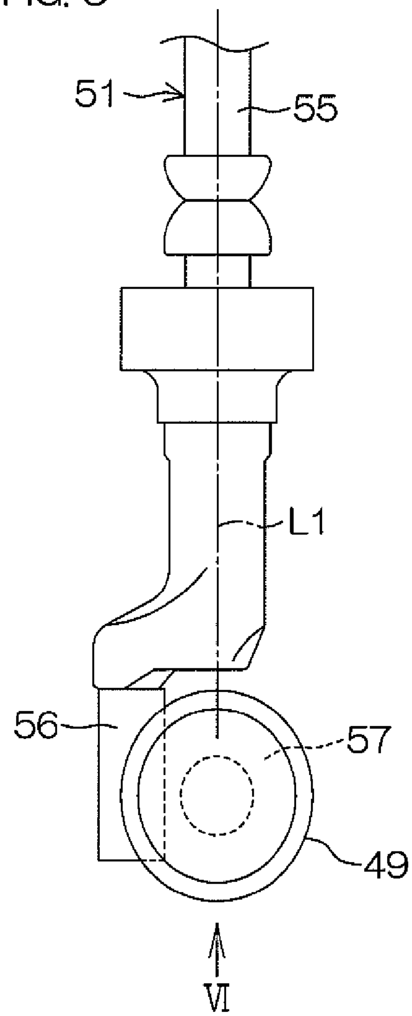
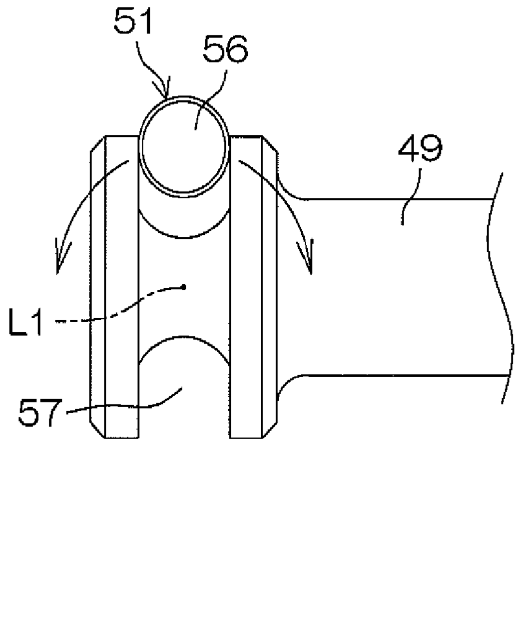


FIG. 6



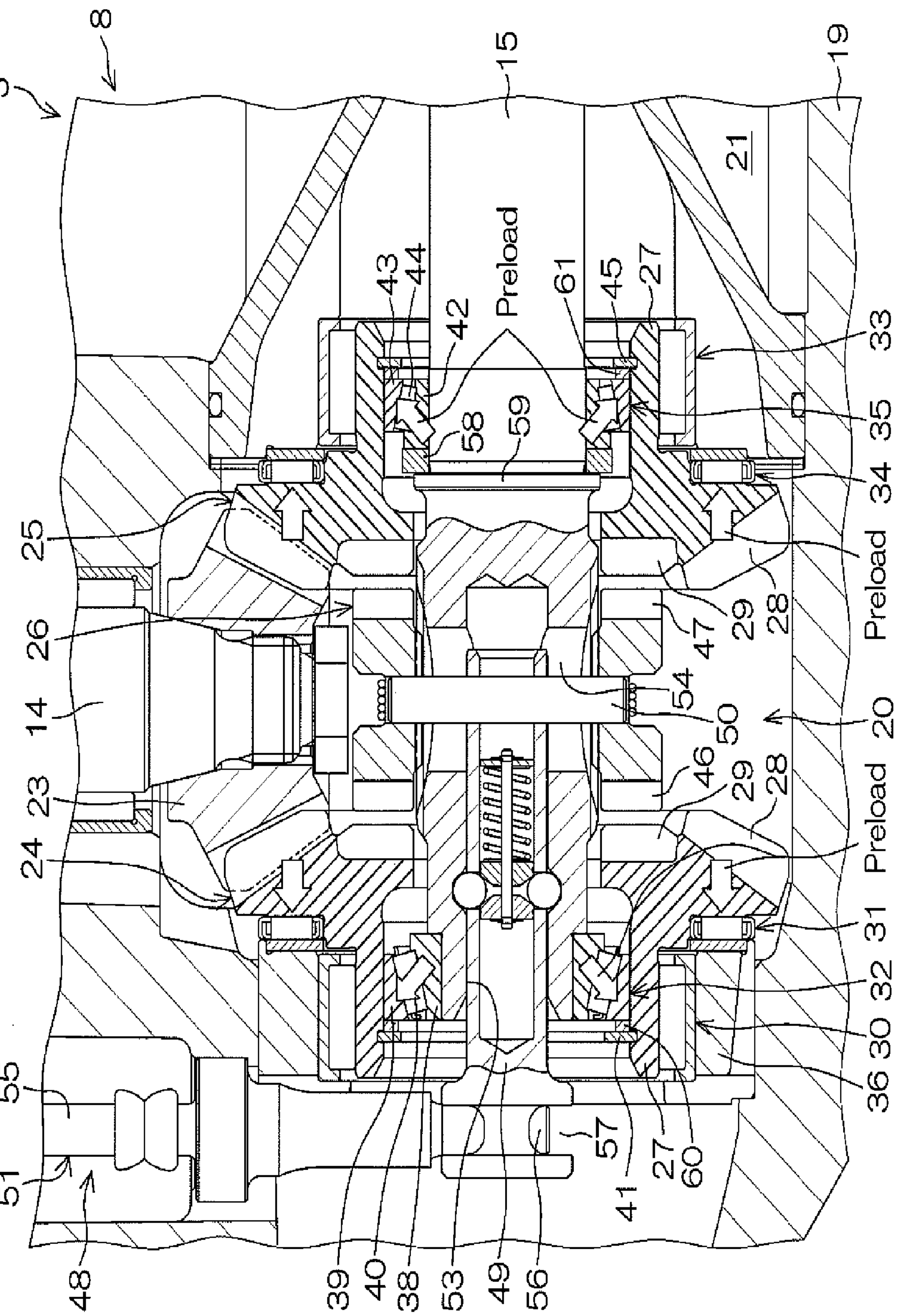

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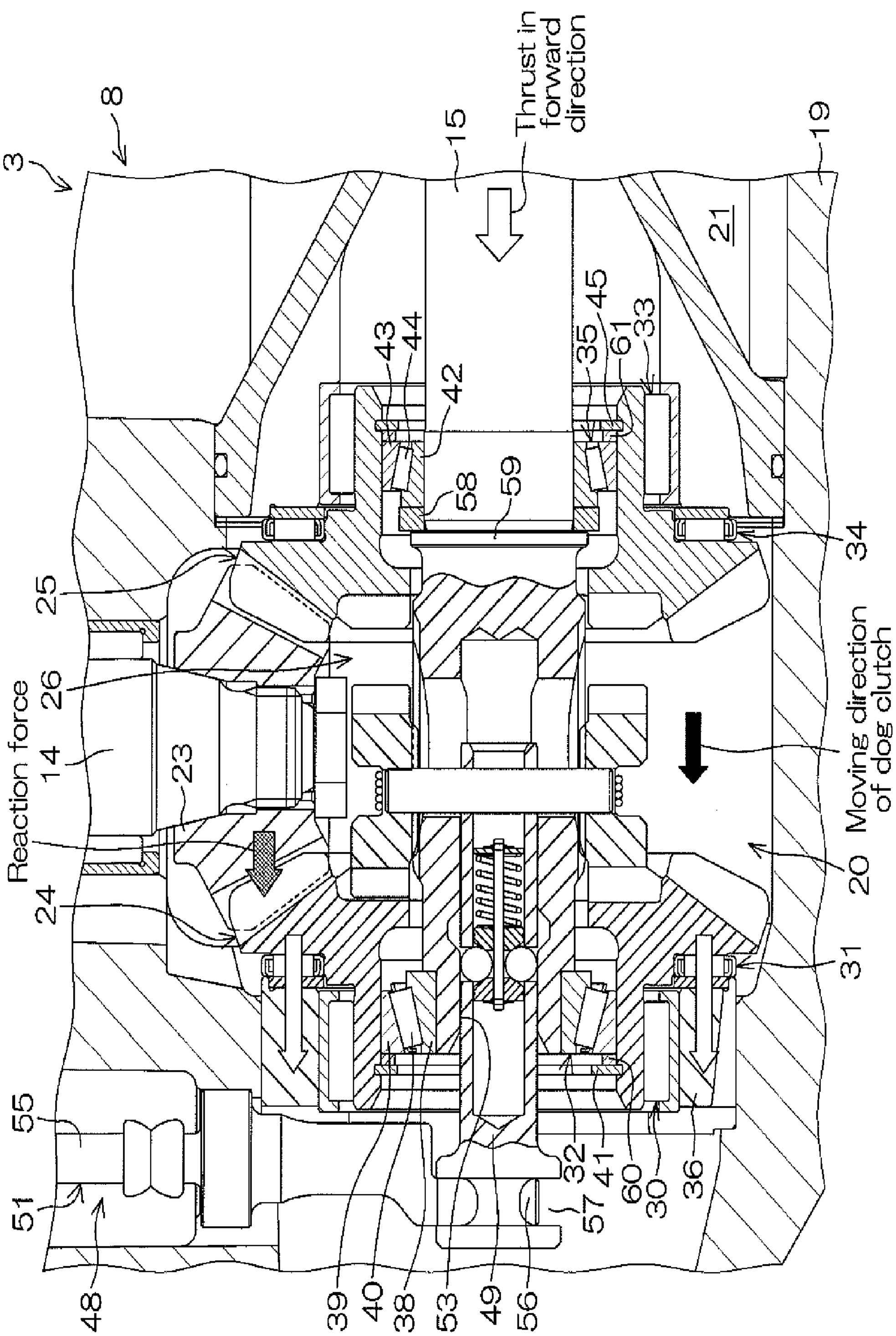
FIG. 7

FIG. 8 Normal rotation specifications · Forward traveling



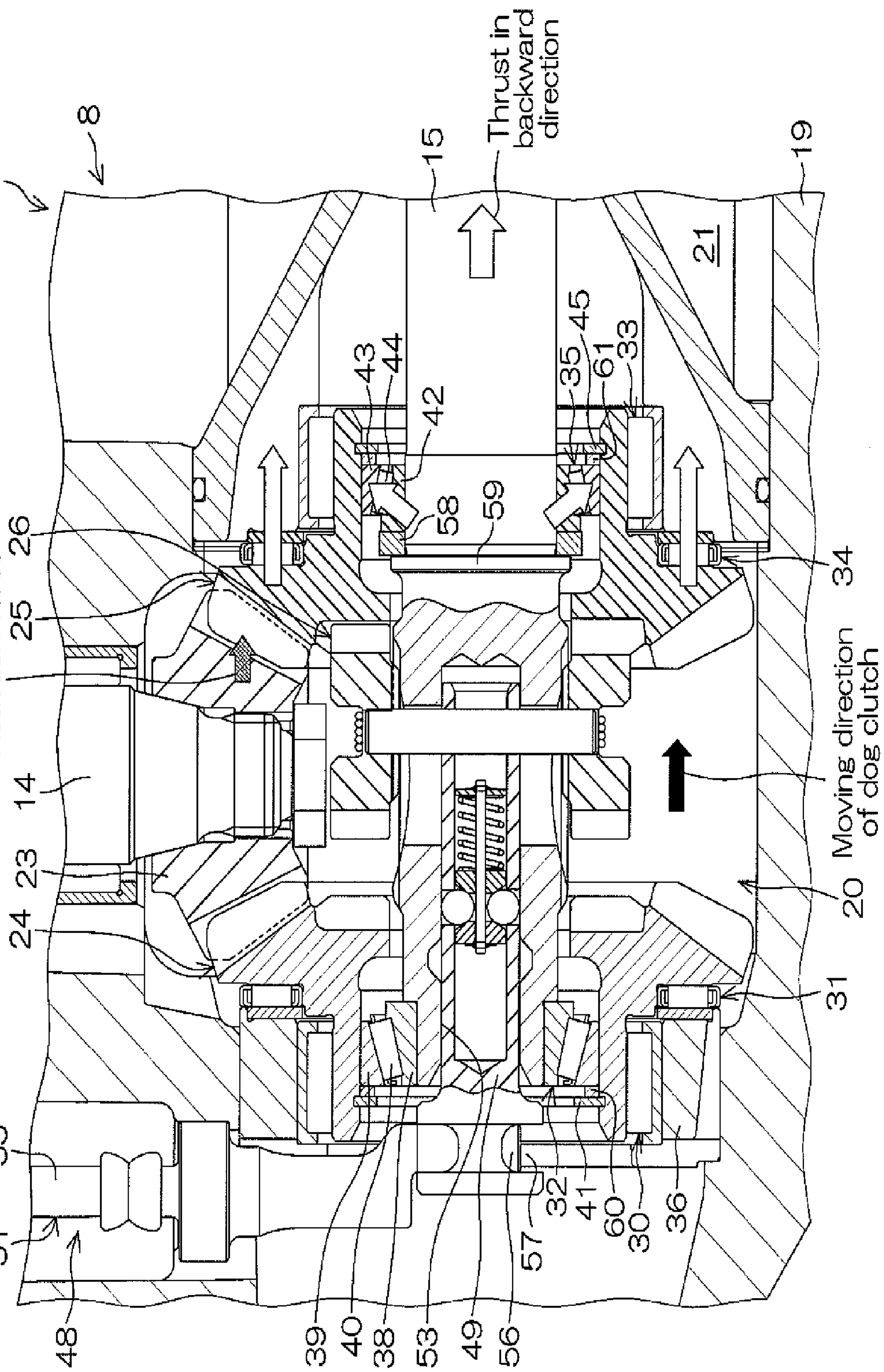


FIG. 9 Normal rotation specifications · Backward traveling Reaction force

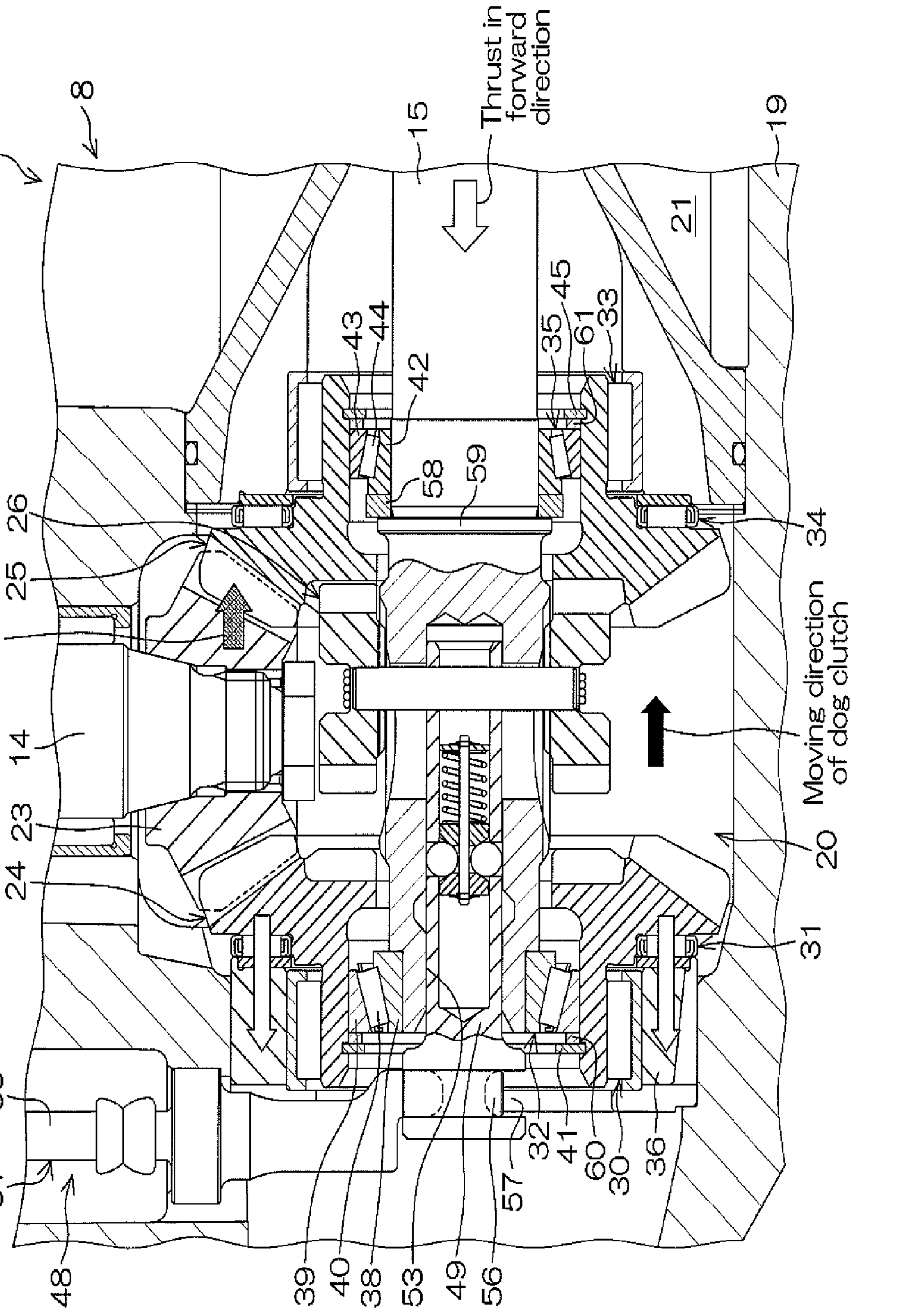


FIG. 10 Reverse rotation specifications · Forward traveling

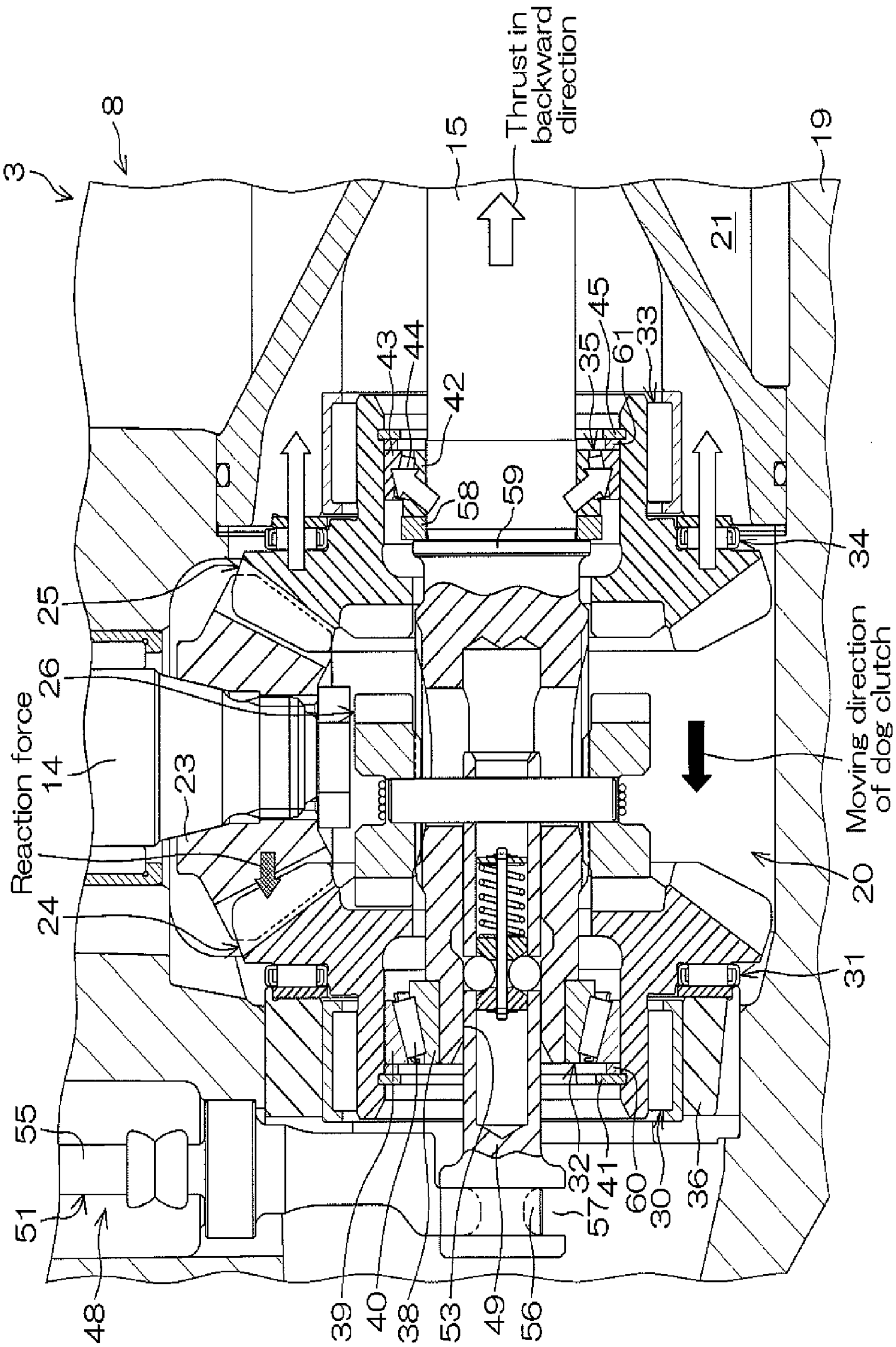
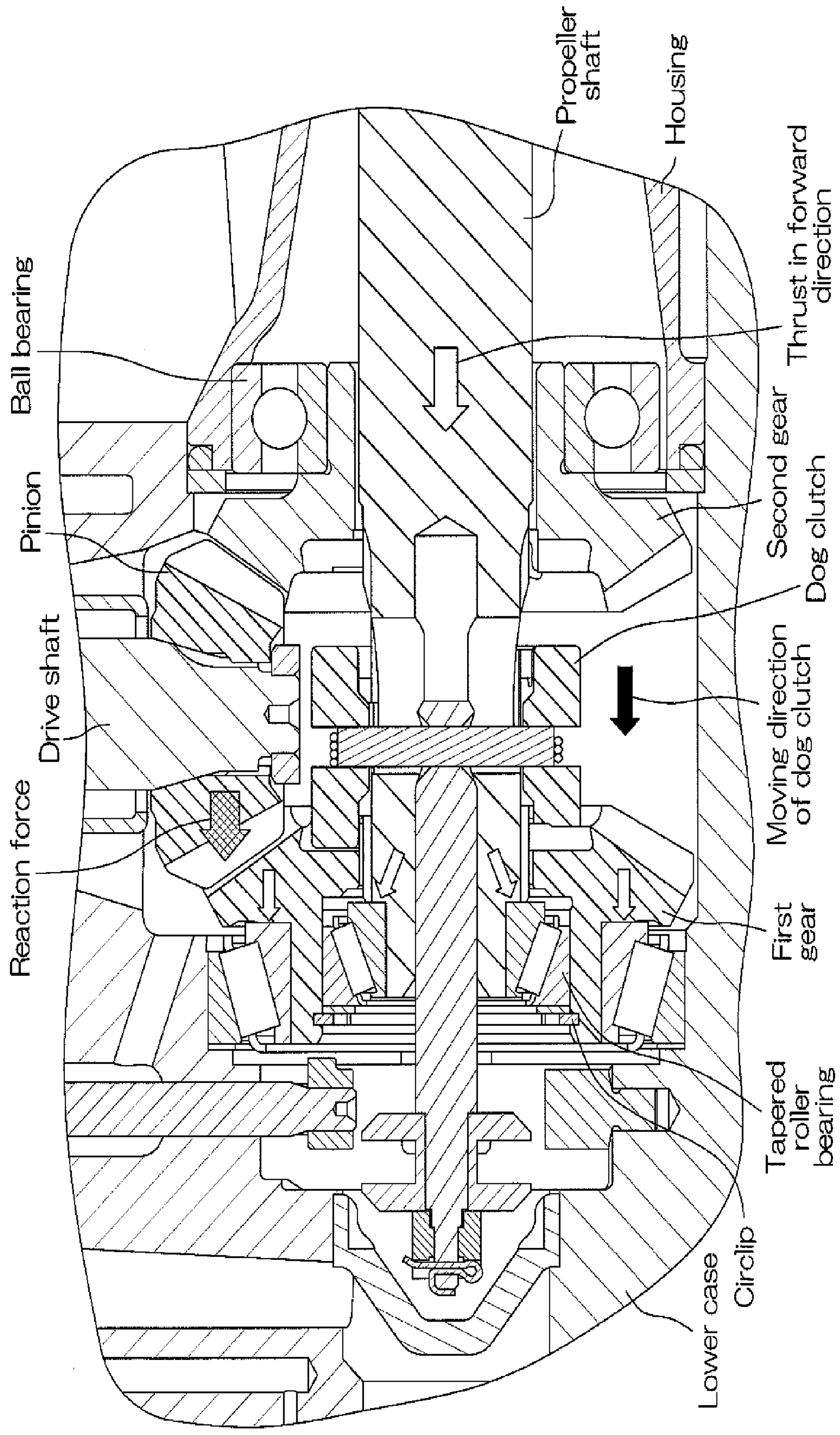


FIG. 11 Reverse rotation specifications · Backward traveling

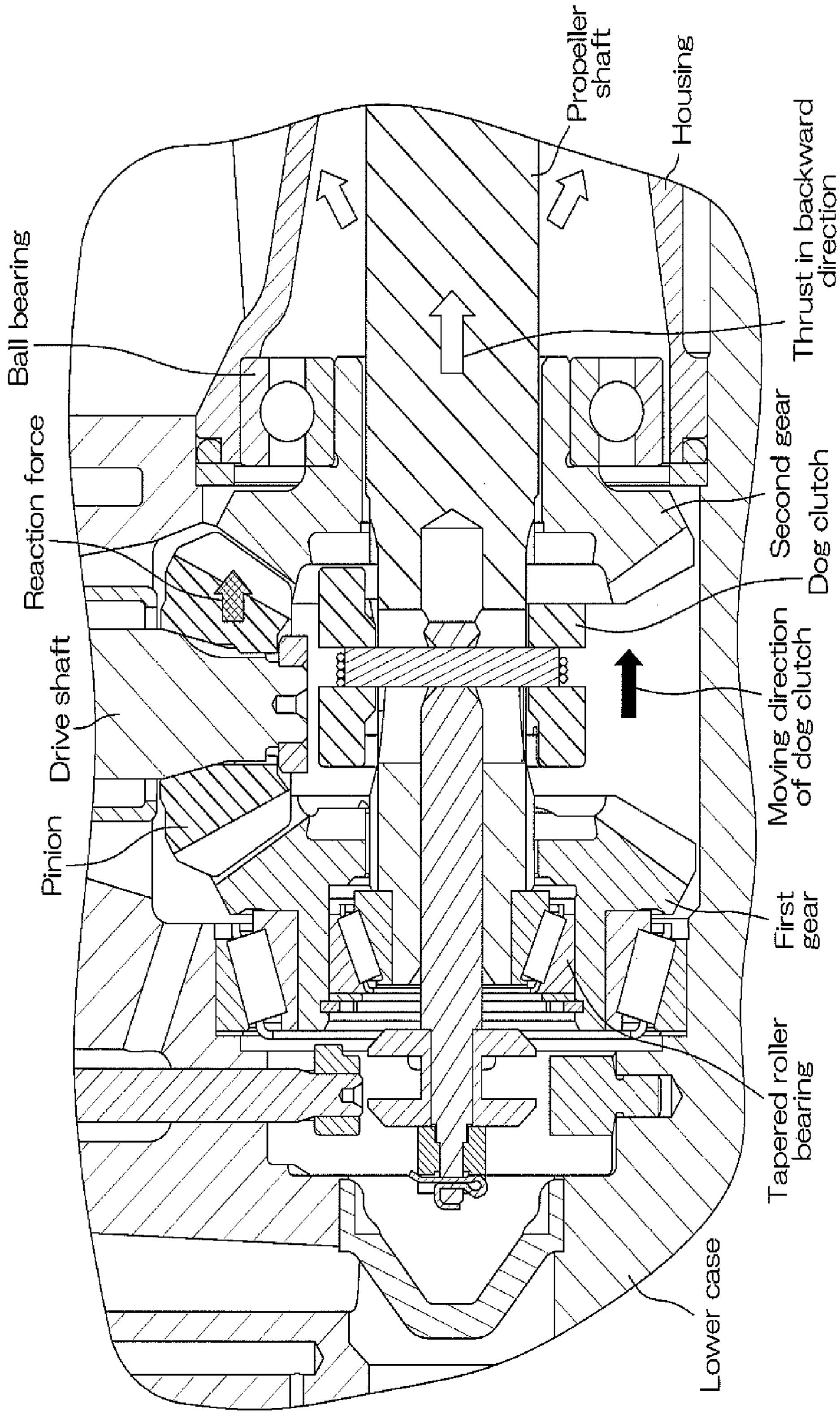
Prior Art

FIG. 12 Ordinary use (Normal rotation specifications · Forward traveling)



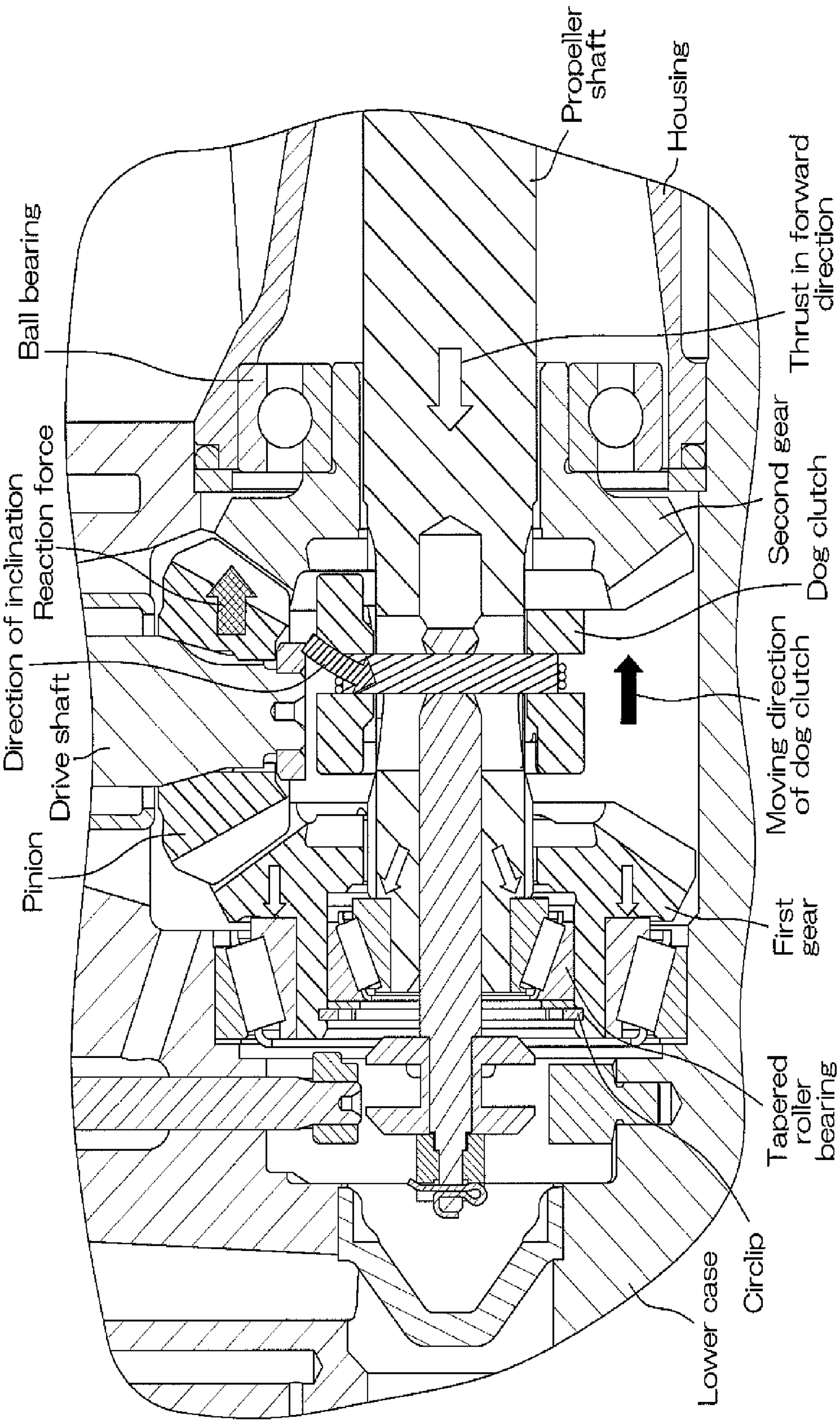
Prior Art

FIG. 13 Ordinary use (Normal rotation specifications · Backward traveling)



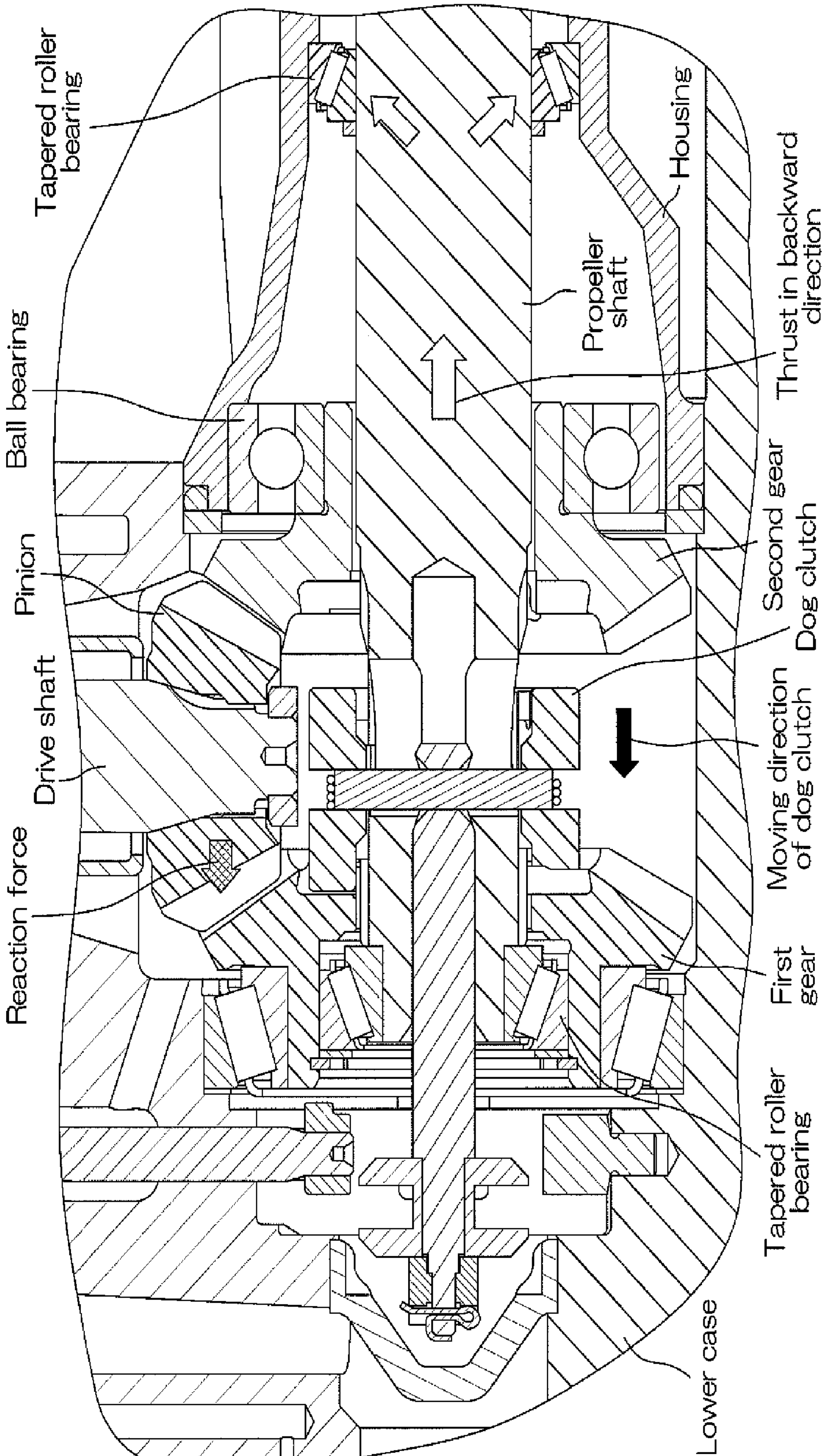
Prior Art

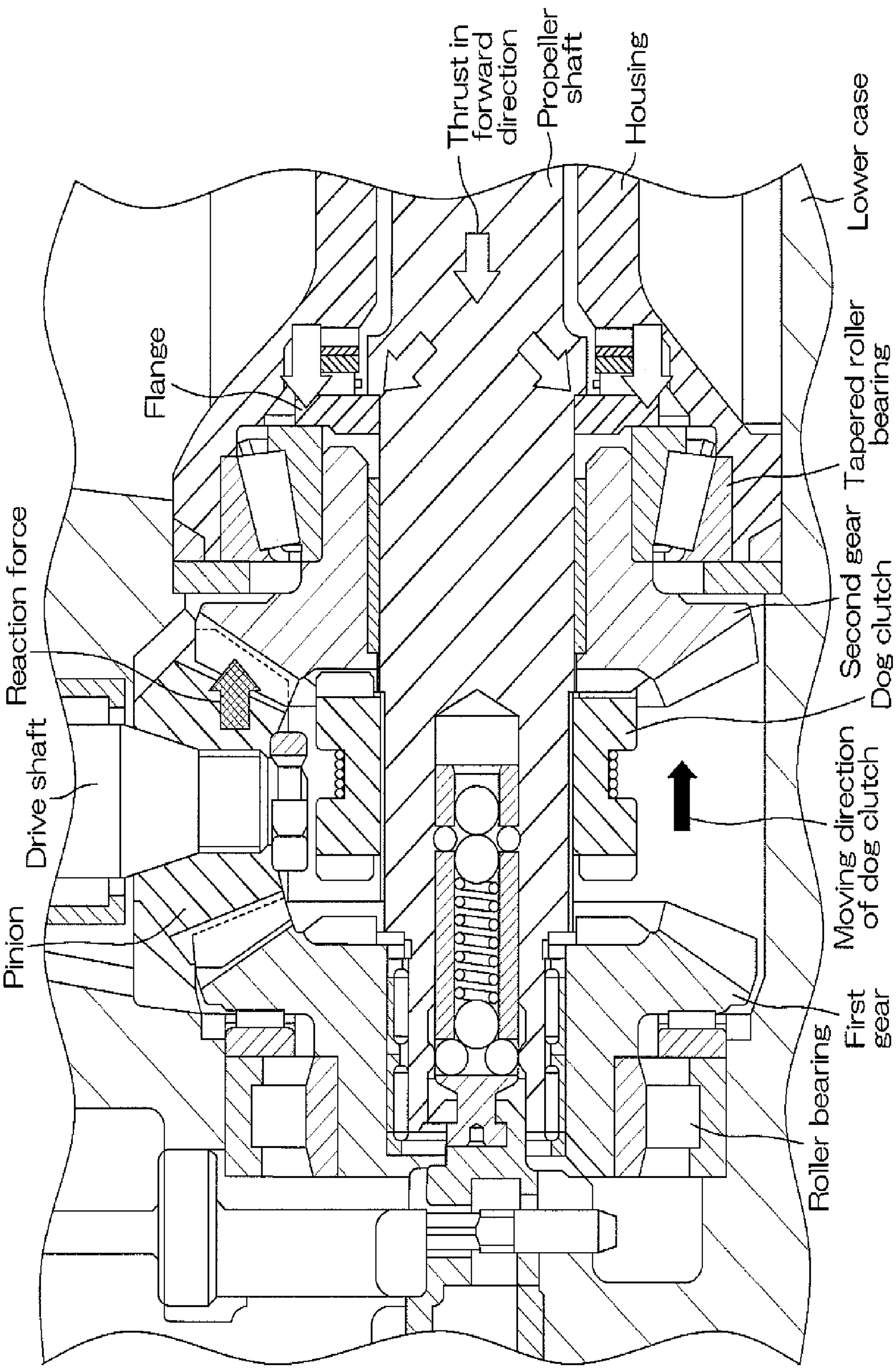
FIG. 14 Non-ordinary use (Reverse rotation specifications · Forward traveling)



Prior Art

FIG. 15 Non-ordinary use (Reverse rotation specifications · Backward traveling)





Prior Art

FIG. 16 Ordinary use (Reverse rotation specifications · Forward traveling)

Prior Art

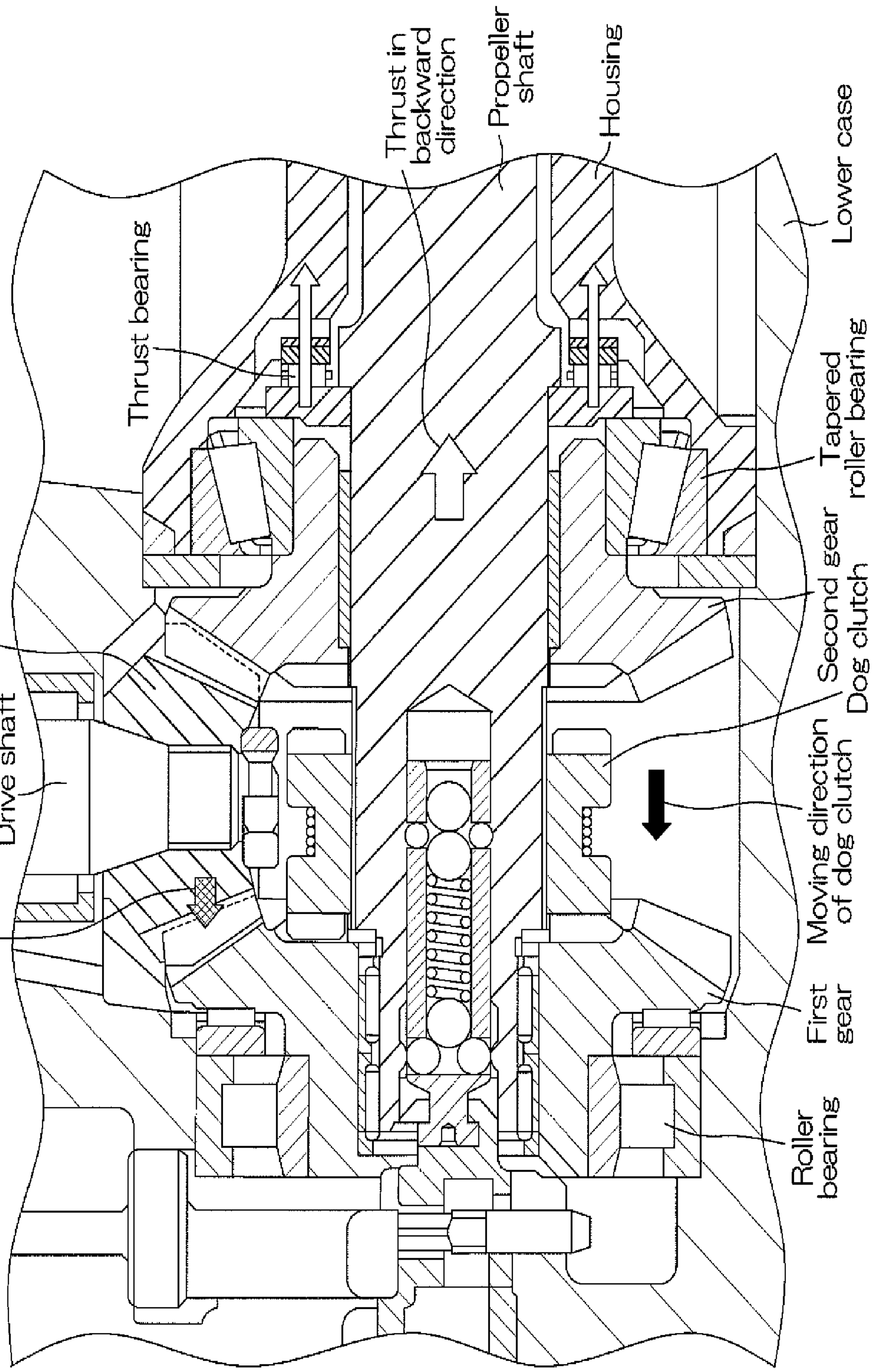
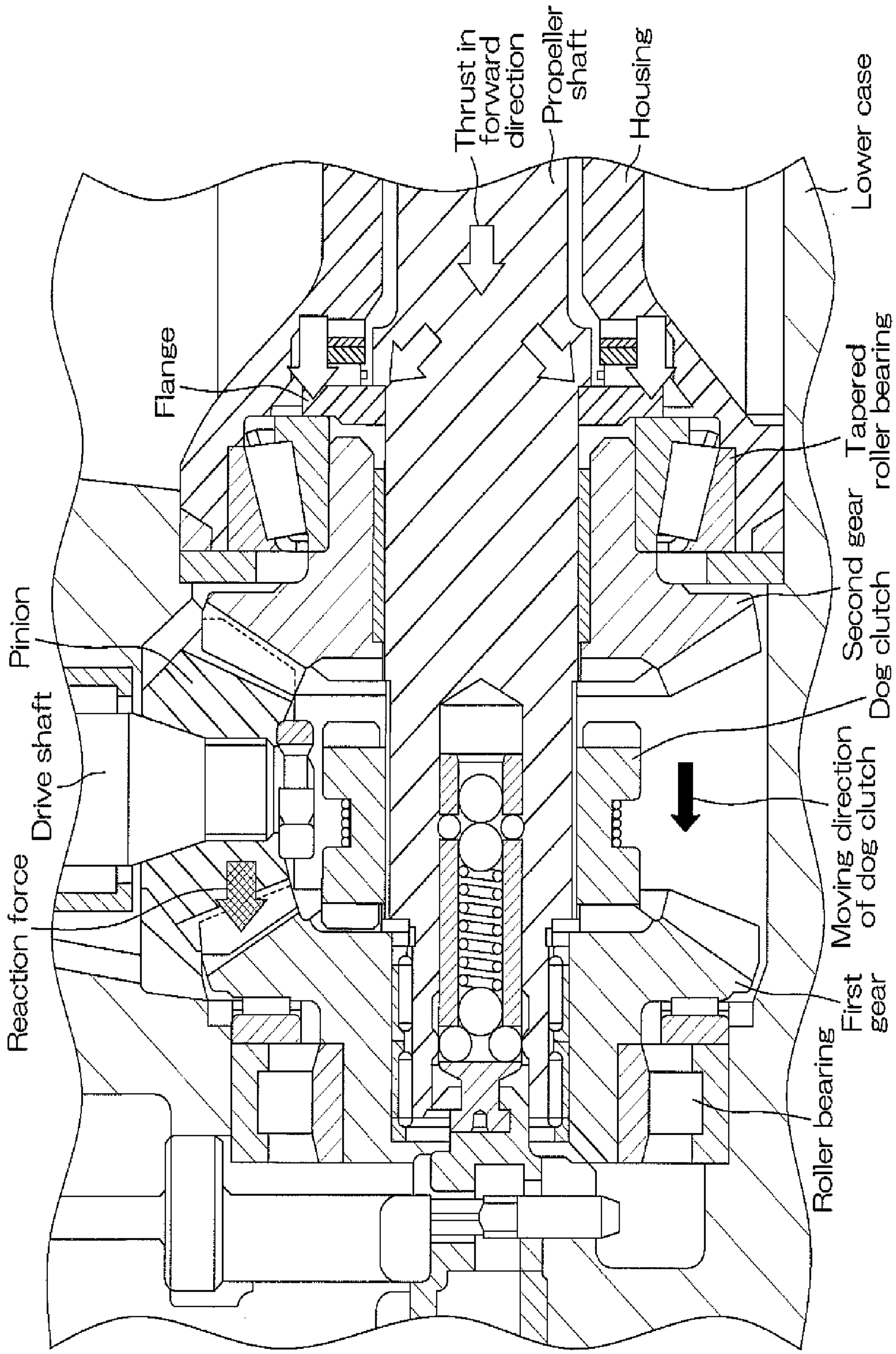
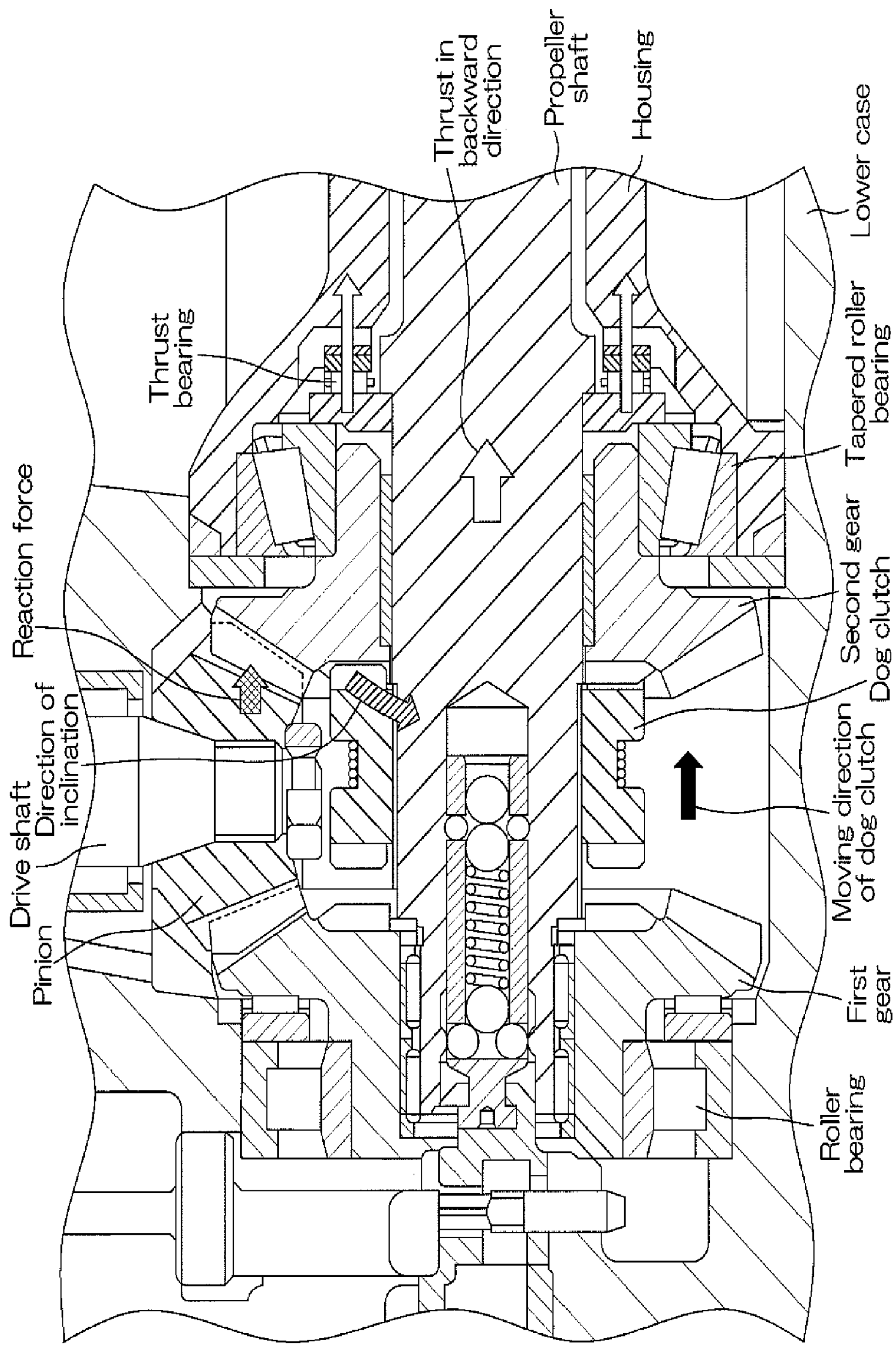


FIG. 17 Ordinary use (Reverse rotation specifications · Backward traveling)

Prior Art

FIG. 18 Non-ordinary use (Normal rotation specifications · Forward traveling)





Prior Art

FIG. 19 Non-ordinary use (Normal rotation specifications · Backward traveling)

VESSEL PROPULSION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a vessel propulsion apparatus.

2. Description of the Related Art

A vessel propulsion apparatus having normal rotation specifications and a vessel propulsion apparatus having reverse rotation specifications are known. A propeller having normal rotation specifications that generates a thrust in a forward direction by rotating in a normal rotation direction is attached to the vessel propulsion apparatus having normal rotation specifications. On the other hand, a propeller having reverse rotation specifications that generates a thrust in the forward direction by rotating in a reverse rotation direction opposite to the normal rotation direction is attached to the vessel propulsion apparatus having reverse rotation specifications.

A conventional vessel propulsion apparatus disclosed in U.S. Pat. No. 7,297,036 is a vessel propulsion apparatus having normal rotation specifications (which is hereinafter referred to simply as a "normal-rotation vessel propulsion apparatus"), whereas a conventional vessel propulsion apparatus disclosed in Japanese Published Unexamined Patent Application No. H11-263294 is a vessel propulsion apparatus having reverse rotation specifications (which is hereinafter referred to simply as a "reverse-rotation vessel propulsion apparatus"). Additionally, a conventional vessel propulsion apparatus disclosed in Japanese Published Unexamined Patent Application No. S63-25829 is a vessel propulsion apparatus having normal/reverse rotation specifications (which is hereinafter referred to simply as a "normal/reverse-rotation vessel propulsion apparatus") that is capable of being used both according to normal rotation specifications and according to reverse rotation specifications.

The normal-rotation vessel propulsion apparatus of U.S. Pat. No. 7,297,036 includes a pinion (drive gear) that rotates together with a drive shaft, a first gear and a second gear that engage with the pinion, a dog clutch that is selectively connected to one of the first and second gears, and a propeller shaft that rotates together with the dog clutch. A propeller having normal rotation specifications (which is hereinafter referred to simply as a "normal-rotation propeller") is attached to the propeller shaft. When the dog clutch is connected to the first gear serving as a forward gear, the propeller shaft and the propeller rotate in a normal rotation direction. On the other hand, when the dog clutch is connected to the second gear serving as a reverse gear, the propeller shaft and the propeller rotate in a reverse rotation direction. Therefore, the rotation direction of the propeller is switched by the dog clutch. The first gear holds the propeller shaft via a tapered roller bearing disposed between the first gear and the propeller shaft, whereas the second gear is held by a housing via a ball bearing (e.g., see FIG. **12**).

The reverse-rotation vessel propulsion apparatus of Japanese Published Unexamined Patent Application No. H11-263294 includes a pinion that rotates together with a drive shaft, a first gear (reverse gear) and a second gear (forward gear) that engage the pinion, a dog clutch that is selectively connected to one of the first and second gears, and a propeller shaft that rotates together with the dog clutch. A propeller having reverse rotation specifications (which is hereinafter referred to simply as a "reverse-rotation propeller") is attached to the propeller shaft. When the dog clutch is connected to the second gear serving as a forward gear, the propeller shaft and the propeller rotate in a reverse rotation direction. On the other hand, when the dog clutch is connected to the first gear serving as a reverse gear, the propeller shaft and the propeller rotate in a normal rotation direction. Therefore, the rotation direction of the propeller is switched by the dog clutch. The first gear is supported by a lower case via a roller bearing, whereas the second gear is supported by a housing via a tapered roller bearing (e.g., see FIG. **16**).

The normal/reverse-rotation vessel propulsion apparatus of Japanese Published Unexamined Patent Application No. S63-25829 includes a pinion (gear) that rotates together with a drive shaft, a first gear (reverse gear) and a second gear (forward gear) that engage the pinion, a dog clutch that is selectively connected to one of the first and second gears, and a propeller shaft that rotates together with the dog clutch. A normal-rotation or reverse-rotation propeller is attached to the propeller shaft. When the dog clutch is connected to the first gear, the propeller shaft and the propeller rotate in a normal rotation direction. On the other hand, when the dog clutch is connected to the second gear, the propeller shaft and the propeller rotate in a reverse rotation direction. Therefore, the rotation direction of the propeller is switched by the dog clutch. Each of the first and second gears surrounds the propeller shaft, and is in a non-contact state with respect to the propeller shaft.

SUMMARY OF THE INVENTION

The inventor of preferred embodiments of the present invention described and claimed in the present application conducted an extensive study and research regarding a vessel propulsion apparatus, such as the one described above, and in doing so, discovered and first recognized new unique challenges and previously unrecognized possibilities for improvements as described in greater detail below.

In detail, the normal-rotation vessel propulsion apparatus and the reverse-rotation vessel propulsion apparatus include lower units, respectively, that differ from each other in structure. Therefore, components for use in the lower unit having normal rotation specifications differ from components for use in the lower unit having reverse rotation specifications, thus making it impossible to achieve a reduction in cost by making these components as dual-use components. Additionally, a retail outlet for such vessel propulsion apparatuses is required to stock components for use in the lower unit having normal rotation specifications and components for use in the lower unit having reverse rotation specifications as spare components used for repairs, and therefore the stock will be increased.

As described above, the normal-rotation or reverse-rotation vessel propulsion apparatus can rotate the propeller both in the normal rotation direction and in the reverse rotation direction by switching the dog clutch. Therefore, in principle, the normal-rotation vessel propulsion apparatus can be used according to reverse rotation specifications by attaching a reverse-rotation propeller to the normal-rotation vessel propulsion apparatus. Likewise, in principle, the reverse-rotation vessel propulsion apparatus can be used according to normal rotation specifications by attaching a normal-rotation propeller to the reverse-rotation vessel propulsion apparatus. However, as described below with regard to the durability of gears, there is a possibility that the durability of gears (pinion, first gear, and second gear) will be decreased if the vessel propulsion apparatus including one of the two different kinds of specifications is used according to the other of the two different kinds of specifications.

In the normal-rotation or reverse-rotation vessel propulsion apparatus, the first gear and the second gear are disposed in front of and behind the pinion, respectively. The pinion always engages the first gear and the second gear, and, when the rotation of the pinion is transmitted to the first gear and to the second gear, the first and second gears rotate in mutually opposite directions. When the propeller is rotated, the dog clutch is connected to one of the first and second gears. Therefore, in the normal-rotation or reverse-rotation vessel propulsion apparatus, the first and second gears have the necessity of being capable of relatively rotating with respect to both the lower case and the propeller shaft. Therefore, it is difficult to fix the position of the first gear and that of the second gear. In other words, it is difficult to hold the first and second gears so as not to perform an operation other than rotation. Therefore, as described below, there is a possibility that the first and second gears are inclined or are moved in an axial direction of the propeller shaft, depending on how to use the vessel propulsion apparatus.

FIG. **12** shows a state of a lower unit when the vessel travels forwardly with the normal-rotation vessel propulsion apparatus. As shown in FIG. **12**, when the normal-rotation vessel propulsion apparatus generates a thrust in the forward direction, a dog clutch is engaged with a first gear serving as a forward gear (see the black arrow). As a result, the rotation of a drive shaft is transmitted to the dog clutch via a pinion and the first gear. A normal-rotation propeller rotates in a normal rotation direction together with the dog clutch and a propeller shaft. A thrust in the forward direction generated by the rotation of the propeller in the normal rotation direction is transmitted to the propeller shaft, a tapered roller bearing, a circlip, the first gear, an outer tapered roller bearing, and a lower case in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion to the first gear is applied to the first gear at an engagement position of the pinion and the first gear (see the crosshatched arrow). As a result, a force by which the first gear is inclined is applied to the first gear. However, the position of the first gear is fixed by the transmission of a thrust in the forward direction to the first gear via the tapered roller bearing, and therefore the first gear will not be easily inclined even if a reaction force is applied to the first gear. Therefore, the engagement between the pinion and the first gear becomes stable, and a force greater than a designed, assumed value is prevented from being applied to the first gear.

FIG. **13** shows a state of the lower unit when the vessel travels backwardly with the normal-rotation vessel propulsion apparatus. As shown in FIG. **13**, when the normal-rotation vessel propulsion apparatus generates a thrust in a backward direction, the dog clutch is engaged with the second gear serving as a reverse gear (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the second gear. The normal-rotation propeller rotates in a reverse rotation direction together with the dog clutch and the propeller shaft. A thrust in the backward direction generated by the rotation of the propeller in the reverse rotation direction is transmitted to the propeller shaft and the housing in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion to the second gear is applied to the second gear at an engagement position of the pinion and the second gear (see the crosshatched arrow). However, when the vessel travels backwardly, torque transmitted from the pinion to the second gear is smaller than when the vessel travels forwardly, and therefore a reaction force applied to the second gear is also smaller. Therefore, the amount of inclination of the second gear is smaller than when the vessel travels forwardly.

FIG. **14** shows a state of the lower unit when the vessel travels forwardly in a case in which the normal-rotation vessel propulsion apparatus is used as a reverse-rotation vessel propulsion apparatus being in a non-ordinary use state. As shown in FIG. **14**, when the normal-rotation vessel propulsion apparatus used according to reverse rotation specifications generates a thrust in the forward direction, the dog clutch is engaged with the second gear serving as a forward gear (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the second gear, and the reverse-rotation propeller rotates in the reverse rotation direction together with the dog clutch and the propeller shaft. A thrust in the forward direction generated by the rotation of the propeller in the reverse rotation direction is transmitted to the propeller shaft, the tapered roller bearing, the circlip, the first gear, the outer tapered roller bearing, and the lower case in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion to the second gear is applied to the second gear (see the crosshatched arrow). This reaction force is applied to a ball bearing, and, as a result, the second gear is greatly inclined by the inclination of the ball bearing (see the hatched arrow). Therefore, there is a possibility that the engagement between the pinion and the second gear will become unstable, and a force greater than a designed, assumed value will be applied to the engagement position of the pinion and the second gear.

FIG. **15** shows a state of the lower unit when the vessel travels backwardly in a case in which the normal-rotation vessel propulsion apparatus is used as a reverse-rotation vessel propulsion apparatus being in a non-ordinary use state. As shown in FIG. **15**, when the normal-rotation vessel propulsion apparatus used according to reverse rotation specifications generates a thrust in the backward direction, the dog clutch is engaged with the first gear serving as a reverse gear (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the first gear, and the reverse-rotation propeller rotates in the normal rotation direction together with the dog clutch and the propeller shaft. A thrust in the backward direction generated by the rotation of the propeller in the normal rotation direction is transmitted to the propeller shaft, the tapered roller bearing, and the housing in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of the rotation from the pinion to the first gear is applied to the first gear at an engagement position of the pinion and the first gear (see the crosshatched arrow). However, when the vessel travels backwardly, the reaction force applied to the first gear is small, and therefore the amount of inclination of the first gear is small.

FIG. **16** shows a state of the lower unit when the vessel travels forwardly with the reverse-rotation vessel propulsion apparatus. As shown in FIG. **16**, when the reverse-rotation vessel propulsion apparatus generates a thrust in the forward direction, the second gear serving as a forward gear is engaged with the dog clutch (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the second gear, and the reverse-rotation propeller rotates in the reverse rotation direction together with the dog clutch and the propeller shaft. In the reverse-rotation vessel propulsion apparatus, a thrust generated by the rotation of the propeller is transmitted via a flange attached to the propeller shaft. A thrust in the forward direction generated by the rotation of the propeller in the reverse rotation direction is transmitted to the propeller shaft, the tapered roller bearing, and the housing in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion to the second gear is applied to the second gear at an engagement position of the pinion and the second gear (see the crosshatched arrow). The direction of the thrust applied to the tapered roller bearing via the propeller shaft is opposite to the direction of the reaction force applied to the tapered roller bearing via the second gear. However, the reaction force applied to the second gear is sufficiently smaller than the magnitude of the thrust applied in the forward direction, and therefore the axial center of the tapered roller bearing becomes stable, and the position of the second gear is fixed. Therefore, the second gear is restrained from being inclined or being moved in the axial direction.

FIG. **17** shows a state of the lower unit when the vessel travels backwardly with the reverse-rotation vessel propulsion apparatus. As shown in FIG. **17**, when the reverse-rotation vessel propulsion apparatus generates a thrust in the backward direction, the dog clutch is engaged with the first gear serving as a reverse gear (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the first gear, and the reverse-rotation propeller rotates in the normal rotation direction together with the dog clutch and the propeller shaft. A thrust in the backward direction generated by the rotation of the propeller in the normal rotation direction is transmitted to the propeller shaft, a thrust bearing, and the housing in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion to the first gear is applied to the first gear at an engagement position of the pinion and the first gear (see the crosshatched arrow). However, the reaction force applied to the first gear is small when the vessel travels backwardly, and therefore the amount of inclination of the first gear is small.

FIG. **18** shows a state of the lower unit when the vessel travels forwardly in a case in which the reverse-rotation vessel propulsion apparatus is used as a normal-rotation vessel propulsion apparatus being in a non-ordinary use state. As shown in FIG. **18**, when the reverse-rotation vessel propulsion apparatus used according to normal rotation specifications generates a thrust in the forward direction, the dog clutch is engaged with the first gear serving as a forward gear (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the first gear, and the normal-rotation propeller rotates in the normal rotation direction together with the dog clutch and the propeller shaft. A thrust in the forward direction generated by the rotation of the propeller in the normal rotation direction is transmitted to the propeller shaft, the tapered roller bearing, and the housing in this order (see the white arrow). At that time, the rotation direction of the propeller shaft and the rotation direction of the tapered roller bearing that supports the second gear are inverted, and therefore the flange of the propeller shaft rotates against the tapered roller bearing. Therefore, wearing of the flange and the tapered roller bearing occurs.

FIG. **19** shows a state of the lower unit when the vessel travels backwardly in a case in which the reverse-rotation vessel propulsion apparatus is used as a normal-rotation vessel propulsion apparatus being in a non-ordinary use state. As shown in FIG. **19**, when the reverse-rotation vessel propulsion apparatus used according to normal rotation specifications generates a thrust in the backward direction, the dog clutch is engaged with the second gear serving as a reverse gear (see the black arrow). As a result, the rotation of the drive shaft is transmitted to the dog clutch via the pinion and the second gear, and the normal-rotation propeller rotates in the reverse rotation direction together with the dog clutch and the propeller shaft. A thrust in the backward direction generated by the rotation of the propeller in the reverse rotation direction is transmitted to the propeller shaft, the thrust bearing, and the housing in this order (see the white arrow). At this time, unlike a case in which the vessel travels forwardly in the ordinary use, only the reaction force caused by the transmission of the rotation from the pinion to the second gear is applied to the second gear (see the crosshatched arrow), and therefore the axial center of the tapered roller bearing is not stabilized, and the second gear becomes unstable, and, as a result, the amount of inclination thereof is increased (see the hatched arrow).

As described above, there is a possibility that the displacement of gears, i.e., the inclination or movement in the axial direction of gears will occur, and the durability of these gears will be decreased if the vessel propulsion apparatus having one of the two different kinds of specifications is used according to the other of the two different kinds of specifications. For example, it is conceivable that a decrease in durability of gears can be prevented if the gears are enlarged. However, if the gears are enlarged, the lower unit of the vessel propulsion apparatus is enlarged, and, as a result, the resistance of water is increased. Therefore, it is preferable to decrease the amount of displacement of each gear as much as possible without enlarging the lower unit of the vessel propulsion apparatus.

It is conceivable that the gear displacement will be prevented by fixing the position of the first gear and that of the second gear. In other words, the inclination or the like of the first and second gears will not occur if the position of the first gear and that of the second gear are fixed, i.e., if the first and second gears are held so as not to perform an operation other than the rotation thereof. However, as described above, the first and second gears must be capable of relatively rotating with respect to both the propeller shaft and the lower case. Therefore, in the conventional vessel propulsion apparatuses, the position of the first gear and that of the second gear are not fixed.

For example, in the normal-rotation vessel propulsion apparatus of U.S. Pat. No. 7,297,036, a thrust in the forward direction is transmitted to the propeller shaft, the tapered roller bearing, and the first gear in this order when the vessel travels forwardly in the ordinary use, and therefore the position of the first gear is fixed when the vessel travels forwardly. However, the position of the first gear is not fixed when a thrust in the forward direction is generated by using this normal-rotation vessel propulsion apparatus according to reverse rotation specifications. In other words, the vessel propulsion apparatus is required to have an intrinsic function to relatively rotate the first and second gears with respect to, for example, the propeller shaft and a function that conflicts with this intrinsic function, i.e., a function to fix the position of the first gear and that of the second gear. To realize these two functions, conventionally, a normal-rotation vessel propulsion apparatus and a reverse-rotation vessel propulsion apparatus have been provided, and these vessel propulsion apparatuses having the two different kinds of specifications have been used properly according to circumstances.

Thus, it is difficult in practice to use the vessel propulsion apparatus having one of the two different kinds of specifications according to the other one although it is possible in principle. Although Japanese Published Unexamined Patent Application No. S63-25829 discloses the normal/reverse-rotation vessel propulsion apparatus, there is a possibility that the first and second gears will be inclined or moved in the axial direction in the same way as above. Therefore, there is a possibility that the durability of the gears will be decreased.

In order to overcome the previously unrecognized and unsolved challenges described above, one preferred embodiment of the present invention provides a vessel propulsion apparatus that includes a first shaft, a drive gear, a first driven gear, a second driven gear, a dog clutch, a second shaft, a first bearing, a second bearing, a case, and an adjusting member. The first shaft is a rotationally driven shaft. The drive gear is connected to the first shaft. The first driven gear and the second driven gear are tubular gears that engage the drive gear. The dog clutch is switched by a shift operation between a connected state in which the dog clutch is connected to one of the first driven gear and the second driven gear and a non-connected state in which the dog clutch is not connected to both the first drive gear and the second drive gear. The second shaft is inserted in the first driven gear and in the second driven gear, is connected to the dog clutch, and is arranged to undergo a thrust. The first bearing is disposed between the first driven gear and the second shaft. The second bearing is disposed between the second driven gear and the second shaft. The case contains the drive gear, the first driven gear, the second driven gear, the dog clutch, the first bearing, and the second bearing. A thrust applied to the second shaft is transmitted to the case via the first bearing and the first driven gear or via the second bearing and the second driven gear. The adjusting member is disposed between the second shaft and at least one of the first driven gear and the second driven gear, and is arranged to apply a preload onto the first bearing and the second bearing.

With this arrangement of the present preferred embodiment of the present invention, the first shaft is rotationally driven, and hence the first driven gear and the second driven gear are rotationally driven by the drive gear. Additionally, the dog clutch is connected to one of the first driven gear and the second driven gear, and hence the rotation of one of the driven gears is transmitted to the second shaft via the dog clutch. Therefore, the rotation of the first shaft is transmitted to the second shaft via the drive gear and so forth. The second shaft is inserted in the first driven gear and in the second driven gear. The first bearing is disposed between the first driven gear and the second shaft, whereas the second bearing is disposed between the second driven gear and the second shaft. A preload is applied onto the first bearing and onto the second bearing by the adjusting member disposed between the second shaft and at least one of the first driven gear and the second driven gear.

As described above, a preload is applied onto the first bearing that rotatably supports the first driven gear and onto the second bearing that rotatably supports the second driven gear, and therefore an internal gap of the first bearing and that of the second bearing can be removed, and the position of the first driven gear and that of the second driven gear can be fixed. In other words, the first driven gear and the second driven gear can be held so as not to perform an operation other than rotation. Therefore, the engagement between the drive gear and each gear (i.e., each of the first and second driven gears) can be prevented from becoming unstable even when the vessel propulsion apparatus is used according to either normal or reverse rotation specifications. This makes it possible to prevent the durability of the gears from being decreased. Therefore, the vessel propulsion apparatus can be used according to either normal or reverse rotation specifications.

The position of each of the first and second gears can be fixed, and the vessel propulsion apparatus can be used according to either normal or reverse rotation specifications as described above, and therefore there is no need to provide special or unique components exclusively for use in each of the two different kinds of specifications. Therefore, it is possible to reduce the production costs and the number of development man-hours of the vessel propulsion apparatus. Additionally, the retail outlet of the vessel propulsion apparatus has no need to stock special or unique components as spare components used for repairs for each of the specifications. Moreover, the first and second bearings and the first and second driven gears can remove their backlashes by applying a preload onto the first and second bearings, and therefore it is possible to prevent the occurrence of an abnormal noise caused by these backlashes.

The first bearing may include a first inner race connected to the second shaft and a first outer race connected to the first driven gear. The second bearing may include a second inner race connected to the second shaft and a second outer race connected to the second driven gear.

The adjusting member may be disposed between the first bearing and the second bearing.

The second shaft may include a flange disposed between the first bearing and the second bearing, and the adjusting member may be disposed between the flange and one of the first bearing and the second bearing.

The case may define an internal space in which the first driven gear and the second driven gear are contained and an opening connected to the internal space, and the second driven gear may be disposed between the opening and the first driven gear. In this case, the adjusting member may be disposed between the second driven gear and the second shaft.

The first driven gear and the second driven gear may be the same in shape. That is, the first driven gear and the second driven gear may be the same type of gear.

Each of the drive gear, the first driven gear, and the second driven gear may include a bevel gear.

Each of the first bearing and the second bearing may include a tapered roller bearing.

The first shaft may include a drive shaft that extends in a vertical direction, and the second shaft may include a propeller shaft that extends in a horizontal direction.

The vessel propulsion apparatus may further include a third bearing disposed between the first driven gear and the case and a fourth bearing disposed between the second driven gear and the case.

Another preferred embodiment of the present invention provides a vessel propulsion apparatus that includes a first shaft, a drive gear, a first driven gear, a second driven gear, a dog clutch, a second shaft, a first bearing, a second bearing, and a case. The first shaft is a rotationally driven shaft. The drive gear is connected to the first shaft. The first driven gear has a tubular shape, and engages the drive gear, and is pressed forwardly. The second driven gear has a tubular shape, and engages the drive gear, and is pressed backwardly. The dog clutch is switched by a shift operation between a connected state in which the dog clutch is connected to one of the first driven gear and the second driven gear and a non-connected state in which the dog clutch is not connected to both the first drive gear and the second drive gear. The second shaft is inserted in the first driven gear and in the second driven gear, and is connected to the dog clutch, and is arranged to undergo a thrust. The first bearing is disposed between the first driven gear and the second shaft. The second bearing is disposed between the second driven gear and the second shaft. The case contains the drive gear, the first driven gear, the second driven gear, the dog clutch, the first bearing, and the second bearing. A thrust applied to the second shaft is transmitted to the case via the first bearing and the first driven gear or via the second bearing and the second driven gear. The vessel propulsion apparatus may further include an adjusting member arranged to press the first driven gear forwardly and to press the second driven gear press backwardly. The adjusting member may be disposed between the second shaft and at least one of the first driven gear and the second driven gear. The adjusting member may be arranged to apply a preload onto the first bearing and the second bearing.

Still another preferred embodiment of the present invention provides a vessel propulsion apparatus that includes a first shaft, a drive gear, a first driven gear, a second driven gear, a dog clutch, a second shaft, a first bearing, a second bearing, a case, and an adjusting member. The first shaft is a rotationally driven shaft. The drive gear is connected to the first shaft. The first driven gear and the second driven gear are tubular, and engage the drive gear. The dog clutch is switched by a shift operation between a connected state in which the dog clutch is connected to one of the first driven gear and the second driven gear and a non-connected state in which the dog clutch is not connected to both the first drive gear and the second drive gear. The second shaft is inserted in the first driven gear and in the second driven gear, and is connected to the dog clutch, and is arranged to undergo a thrust. The first bearing is disposed between the first driven gear and the second shaft. The second bearing is disposed between the second driven gear and the second shaft. The case contains the drive gear, the first driven gear, the second driven gear, the dog clutch, the first bearing, and the second bearing. A thrust applied to the second shaft is transmitted to the case via the first bearing and the first driven gear or via the second bearing and the second driven gear. The adjusting member is disposed between the second driven gear and the second shaft, and is arranged to apply a preload onto the first bearing and the second bearing. The second shaft includes a flange disposed between the dog clutch and the second bearing. The adjusting member is disposed between the flange and the second bearing.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of a vessel according to a first preferred embodiment of the present invention.

FIG. **2** is a side view of the vessel propulsion apparatus according to the first preferred embodiment of the present invention.

FIG. **3** is a sectional view of a lower unit of the outboard motor according to the first preferred embodiment of the present invention.

FIG. **4** is an enlarged view of a portion of FIG. **3**.

FIG. **5** is a view of a slider and a cam according to the first preferred embodiment of the present invention, viewed from the direction of arrow V of FIG. **3**.

FIG. **6** is a view of the slider and the cam according to the first preferred embodiment of the present invention, viewed from the direction of arrow VI of FIG. **5**.

FIG. **7** is a view for describing a preload applied onto the first tapered roller bearing and onto the second tapered roller bearing according to the first preferred embodiment of the present invention.

FIG. **8** is a sectional view of the lower unit of the outboard motor according to the first preferred embodiment of the present invention.

FIG. **9** is a sectional view of the lower unit of the outboard motor according to the first preferred embodiment of the present invention.

FIG. **10** is a sectional view of the lower unit of the outboard motor according to the first preferred embodiment of the present invention.

FIG. **11** is a sectional view of the lower unit of the outboard motor according to the first preferred embodiment of the present invention.

FIG. **12** is a sectional view for describing a force transmission path when a conventional normal-rotation vessel propulsion apparatus generates a thrust in a forward direction.

FIG. **13** is a sectional view for describing a force transmission path when a conventional normal-rotation vessel propulsion apparatus generates a thrust in a backward direction.

FIG. **14** is a sectional view for describing a force transmission path when the conventional normal-rotation vessel propulsion apparatus is used according to reverse rotation specifications and generates a thrust in the forward direction.

FIG. **15** is a sectional view for describing a force transmission path when the conventional normal-rotation vessel propulsion apparatus is used according to reverse rotation specifications and generates a thrust in the backward direction.

FIG. **16** is a sectional view for describing a force transmission path when a conventional reverse-rotation vessel propulsion apparatus generates a thrust in a forward direction.

FIG. **17** is a sectional view for describing a force transmission path when a conventional reverse-rotation vessel propulsion apparatus generates a thrust in a backward direction.

FIG. **18** is a sectional view for describing a force transmission path when the conventional reverse-rotation vessel propulsion apparatus is used according to normal rotation specifications and generates a thrust in the forward direction.

FIG. **19** is a sectional view for describing a force transmission path when the conventional reverse-rotation vessel propulsion apparatus is used according to normal rotation specifications and generates a thrust in the backward direction.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Preferred Embodiment

FIG. **1** is a plan view of a vessel **1** according to a first preferred embodiment of the present invention.

The vessel **1** preferably includes a hull **2**, two vessel propulsion apparatuses **3** that generate a thrust, a handle **4** operated by a vessel operator to steer the vessel **1**, and a remote control **5** operated by the vessel operator to perform switching between forward traveling and backward traveling of the vessel **1** and to adjust vessel speed. The handle **4** and the remote control **5** are disposed at a vessel operating portion **6** provided in the hull **2**. The two vessel propulsion apparatuses **3** are attached to the rear portion of the hull **2**. Each vessel propulsion apparatus **3** is a normal/reverse-rotation vessel propulsion apparatus that can be used according to both normal rotation specifications and reverse rotation specifications. One of the vessel propulsion apparatuses **3** is used according to normal rotation specifications, and a normal-rotation propeller **7***a* that generates a thrust in a forward direction by rotating in a normal rotation direction (e.g., clockwise when viewed from behind) is attached to this vessel propulsion apparatus **3**. The other vessel propulsion apparatus **3** is used according to reverse rotation specifications, and a reverse-rotation propeller **7***b* that generates a thrust in the forward direction by rotating in a reverse rotation direction opposite to the normal rotation direction is attached to this vessel propulsion apparatus **3**. The rotation direction and the rotation speed of each propeller **7** are changed by the remote control **5** operated by the vessel operator.

FIG. **2** is a side view of the vessel propulsion apparatus **3** according to the first preferred embodiment of the present invention.

The vessel propulsion apparatus **3** includes an outboard motor **8** that generates a thrust. The vessel propulsion apparatus **3** additionally includes a clamping bracket **9**, a swivel bracket **10**, and a steering shaft **11**. The swivel bracket **10** is connected to the clamping bracket **9**. The steering shaft **11** is held by the swivel bracket **10** rotatably around a central axis. The outboard motor **8** is connected to the steering shaft **11**. The clamping bracket **9** is attached to a transom **12** provided at the rear portion of the hull **2**. Therefore, the outboard motor **8** is attached to the transom **12** via the clamping bracket **9**, the swivel bracket **10**, and the steering shaft **11**. The outboard motor **8** is arranged rotatably around the steering shaft **11** with respect to the clamping bracket **9** and the swivel bracket **10**. The outboard motor **8** laterally rotates around the steering shaft **11** while the vessel operator is operating the handle **4**. As a result, the vessel **1** is steered.

The outboard motor **8** includes an engine **13** that generates power, a drive shaft **14** that is rotationally driven by the engine **13** in a predetermined direction, and a propeller shaft **15** to which the rotation of the drive shaft **14** is transmitted. The outboard motor **8** additionally includes an engine cover **16** in which the engine **13** is placed, and a casing **17** disposed below the engine cover **16**. The casing **17** includes an upper case **18** and a lower case **19** disposed below the upper case **18**. The drive shaft **14** extends in a vertical direction inside the upper and lower cases **18** and **19**. An upper end portion of the drive shaft **14** is connected to the engine **13**. A lower end portion of the drive shaft **14** is connected to the propeller shaft **15** via a gear mechanism **20**. The propeller shaft **15** extends in a horizontal direction inside the lower case **19**. A rear end portion of the propeller shaft **15** protrudes backwardly from the lower case **19**. The propeller **7** is connected to the rear end portion of the propeller shaft **15**. The propeller **7** is rotationally driven by the engine **13**. The propeller **7** rotates in the normal rotation direction and in the reverse rotation direction together with the propeller shaft **15**.

FIG. **3** is a sectional view of a lower unit of the outboard motor **8** according to the first preferred embodiment of the present invention, and FIG. **4** is an enlarged view of a portion of FIG. **3**. FIG. **5** is a view of a slider **49** and a cam **51** according to the first preferred embodiment of the present invention, viewed from the direction of arrow V of FIG. **3**. FIG. **6** is a view of the slider **49** and the cam **51** according to the first preferred embodiment of the present invention, viewed from the direction of arrow VI of FIG. **5**. Hereinafter, reference is made to FIG. **3** and FIG. **4**. Reference to FIG. **5** and FIG. **6** is appropriately made if necessary.

The outboard motor **8** includes the gear mechanism **20** that transmits the rotation of the drive shaft **14** to the propeller shaft **15**. The gear mechanism **20** is contained in an internal space **21** defined inside the lower case **19**. The gear mechanism **20**, a housing **37**, and so on are built into the internal space **21** from an opening **22** provided in a rear surface of the lower case **19**. The gear mechanism **20** includes a pinion **23** connected to the lower end portion of the drive shaft **14**, a first gear **24** and a second gear **25** that engage the pinion **23**, and a dog clutch **26** that is selectively connected to one of the first and second gears **24** and **25**. Each of the pinion **23** and the first and second gears **24** and **25** is, for example, a bevel gear. The first and second gears **24** and **25** face each other in a front-rear direction. The dog clutch **26** is disposed between the first and second gears **24** and **25**. Each of the first and second gears **24**, **25** and the dog clutch **26** is cylindrical, and the propeller shaft **15** is inserted in the first and second gears **24**, **25** and the dog clutch **26**. The pinion **23** engages the first and second gears **24** and **25**, and therefore, when the pinion **23** rotates, the first and second gears **24** and **25** rotate in mutually opposite directions.

The first and second gears **24** and **25** are, for example, the same type of gear. Therefore, the first and second gears **24** and **25** are the same in shape and in material. Each of the first and second gears **24** and **25** includes a cylindrical portion **27**, a cylindrical tooth portion **28** that has an outer diameter greater than the cylindrical portion **27**, and a cylindrical engagement portion **29** disposed inside the tooth portion **28**. The corresponding cylindrical portion **27**, tooth portion **28**, and engagement portion **29** are coaxial. The propeller shaft **15** is inserted inside the cylindrical portions **27**, the tooth portions **28**, and the engagement portions **29** of the first and second gears **24** and **25**. The first and second gears **24** and **25** are arranged so as to be relatively rotatable with respect to the propeller shaft **15** and the lower case **19** via a plurality of bearings **30** to **35** provided in the outboard motor **8**.

In detail, the outboard motor **8** includes a cylindrical adaptor **36** held by the lower case **19**. The cylindrical portion **27** of the first gear **24** is inserted in the adaptor **36** so that the tooth portion **28** of the first gear **24** is located behind the adaptor **36** (i.e., at the right side in FIGS. **3** and **4**). A first roller bearing **30** is disposed between the adaptor **36** and the cylindrical portion **27** of the first gear **24**, and a first thrust bearing **31** is disposed between the adaptor **36** and the tooth portion **28** of the first gear **24**. The first gear **24** is rotatably held by the adaptor **36** via the first roller bearing **30** and the first thrust bearing **31**. Therefore, the first gear **24** is relatively rotatable with respect to the lower case **19**. A first tapered roller bearing **32** is disposed between the cylindrical portion **27** of the first gear **24** and the propeller shaft **15**. The propeller shaft **15** is held by the first gear **24** via the first tapered roller bearing **32**. Therefore, the first gear **24** is relatively rotatable with respect to the propeller shaft **15**.

The outboard motor **8** additionally includes a cylindrical housing **37** held by the lower case **19**. The cylindrical portion **27** of the second gear **25** is inserted in the housing **37** so that the tooth portion **28** of the second gear **25** is located in front of the housing **37** (i.e., at the left side in FIGS. **3** and **4**). A second roller bearing **33** is disposed between the housing **37** and the cylindrical portion **27** of the second gear **25**, and a second thrust bearing **34** is disposed between the housing **37** and the tooth portion **28** of the second gear **25**. The first roller bearing **30** and the second roller bearing **33** preferably are, for example, the same type of bearing, and the first thrust bearing **31** and the second thrust bearing **34** are, for example, the same type of bearing (roller bearings). The second gear **25** is rotatably held by the housing **37** via the second roller bearing **33** and the second thrust bearing **34**. Therefore, the second gear **25** is relatively rotatable with respect to the lower case **19**. A second tapered roller bearing **35** is disposed between the cylindrical portion **27** of the second gear **25** and the propeller shaft **15**. The propeller shaft **15** is held by the second gear **25** via the second tapered roller bearing **35**. Therefore, the second gear **25** is relatively rotatable with respect to the propeller shaft **15**.

The first tapered roller bearing **32** includes a cylindrical first inner race **38** that surrounds the propeller shaft **15**, a cylindrical first outer race **39** that surrounds the first inner race **38**, and a plurality of first rollers **40** disposed between the first inner race **38** and the first outer race **39**. The first inner race **38** is connected to the propeller shaft **15**, and the first outer race **39** is connected to the first gear **24**. The first rollers **40** are disposed along a conic surface that tapers toward the front. The first tapered roller bearing **32** is disposed in the first gear **24** (i.e., in the cylindrical portion **27**). The first tapered roller bearing **32** is prevented from moving from the inside of the first gear **24** by a first circlip **41** and a washer **60** disposed in the first gear **24**.

On the other hand, the second tapered roller bearing **35** includes a cylindrical second inner race **42** that surrounds the propeller shaft **15**, a cylindrical second outer race **43** that surrounds the second inner race **42**, and a plurality of second rollers **44** disposed between the second inner race **42** and the second outer race **43**. The second inner race **42** is connected to the propeller shaft **15**, and the second outer race **43** is connected to the second gear **25**. The second rollers **44** are disposed along a conic surface that tapers toward the rear. The second tapered roller bearing **35** is disposed in the second gear **25** (i.e., in the cylindrical portion **27**). The second tapered roller bearing **35** is prevented from moving from the inside of the second gear **25** by the second circlip **45** and the washer **61** disposed in the second gear **25**.

The dog clutch **26** is disposed between the engagement portion **29** of the first gear **24** and the engagement portion **29** of the second gear **25**. The dog clutch **26** includes a first engagement portion **46** that faces the engagement portion **29** of the first gear **24** and a second engagement portion **47** that faces the engagement portion **29** of the second gear **25**. The dog clutch **26** is connected to the propeller shaft **15** by, for example, a spline. Therefore, the dog clutch **26** rotates together with the propeller shaft **15**. Additionally, the dog clutch **26** is movable along the propeller shaft **15** in the axial direction of the propeller shaft **15** (in the front-rear direction). The dog clutch **26** is placed at any shift position of a normal rotation position at which the engagement portion **29** of the first gear **24** engages the first engagement portion **46**, a reverse rotation position at which the engagement portion **29** of the second gear **25** engages the second engagement portion **47**, and a neutral position at which the dog clutch **26** is spaced away from the first and second gears **24** and **25**.

In detail, the outboard motor **8** includes a shift mechanism **48** that switches the shift position of the dog clutch **26**. The shift mechanism **48** includes a slider **49** inserted in the front end portion of the propeller shaft **15**, a connection pin **50** that connects the slider **49** and the dog clutch **26** together, a cam **51** that moves the slider **49** in the front-rear direction, and a shift actuator **52** that rotates the cam **51**. The slider **49** is inserted in an insertion hole **53** provided in the propeller shaft **15**. The insertion hole **53** extends backwardly from the front end of the propeller shaft **15** along a central axis of the propeller shaft **15**. The slider **49** is movable in the front-rear direction along the insertion hole **53**. The front end portion of the slider **49** protrudes forwardly from the front end of the propeller shaft **15**, whereas the rear end portion of the slider **49** is disposed in a through-hole **54** provided in the propeller shaft **15**. The through-hole **54** perpendicularly or substantially perpendicularly intersects with the insertion hole **53**, and penetrates the propeller shaft **15**.

The connection pin **50** is connected to the slider **49** at the inside of the propeller shaft **15**, i.e., at the intersection of the insertion hole **53** and the through-hole **54**. The connection pin **50** perpendicularly intersects with the propeller shaft **15**, and both end portions of the connection pin **50** protrude from the propeller shaft **15**. Both end portions of the connection pin **50** are connected to the dog clutch **26** between the first engagement portion **46** and the second engagement portion **47**. The dog clutch **26** and the slider **49** are connected together so as to be moved as one in the axial direction of the propeller shaft **15** via the connection pin **50**. The through-hole **54** is a hole that is long in the axial direction of the propeller shaft **15**. The dog clutch **26**, the slider **49**, and the connection pin **50** are movable in the front-rear direction within the range of the length of the through-hole **54**.

The cam **51** includes a rod portion **55** extending in the vertical direction and a pin portion **56**. The pin portion **56** protrudes downwardly from the rod portion **55**. As shown in FIG. **5**, the pin portion **56** is eccentric with respect to the rod portion **55**. As shown in FIGS. **5** and **6**, the pin portion **56** is inserted in an annular groove **57** provided on the front end portion of the slider **49**. The annular groove **57** surrounds the front end portion of the slider **49**. The pin portion **56** is inserted in the annular groove **57** at the right or left of the slider **49**. When a shift operation to switch the traveling direction of the vessel **1** is performed by the vessel operator, the shift actuator **52** rotates the cam **51** around a central axis L1 of the rod portion **55**. The pin portion **56** is eccentric with respect to the rod portion **55**, and therefore, as shown in FIG. **6**, the pin portion **56** moves in the front-rear direction (in the right-left direction in FIG. **6**) while rotating around the central axis L1 of the rod portion **55** in response to the rotation of the cam **51**. Therefore, the slider **49** moves in the front-rear direction together with the connection pin **50** and the dog clutch **26** in response to the rotation of the cam **51**. In other words, the dog clutch **26** is placed at any of the normal rotation position, the reverse rotation position, and the neutral position by the rotation of the cam **51**.

In a state in which the dog clutch **26** is placed at the normal rotation position, the rotation of the drive shaft **14** transmitted to the first gear **24** via the pinion **23** is transmitted to the dog clutch **26** via the engagement portion **29** of the first gear **24** and the first engagement portion **46** of the dog clutch **26**. As a result, the propeller shaft **15** and the propeller **7** rotate in the normal rotation direction. On the other hand, in a state in which the dog clutch **26** is placed at the reverse rotation position, the rotation of the drive shaft **14** transmitted to the second gear **25** via the pinion **23** is transmitted to the dog clutch **26** via the engagement portion **29** of the second gear **25** and the second engagement portion **47** of the dog clutch **26**. As a result, the propeller shaft **15** and the propeller **7** rotate in the reverse rotation direction. In a state in which the dog clutch **26** is placed at the neutral position (i.e., the position shown in FIGS. **3** and **4**), the dog clutch **26** is not connected to either of the first and second gears **24** and **25**, and therefore the rotation of the drive shaft **14** is not transmitted to the propeller shaft **15** and the propeller **7**, and the first and second gears **24** and **25** rotate idle.

Even in a case in which the vessel propulsion apparatus **3** is used according to either of the normal and reverse rotation specifications, the cam **51** is driven in one rotation direction around the central axis L1 of the rod portion **55** when a forward shift operation to switch the traveling direction of the vessel **1** to the forward traveling is performed by the remote control **5** operated by the vessel operator. Likewise, even in a case in which the vessel propulsion apparatus **3** is used according to either of the normal and reverse rotation specifications, the cam **51** is driven in the other rotation direction (i.e., direction opposite to the one rotation direction) around the central axis L1 of the rod portion **55** when a backward shift operation to switch the traveling direction of the vessel **1** to the backward traveling is performed by the remote control **5** operated by the vessel operator. In other words, the rotation direction of the cam **51** is predetermined for each shift operation in spite of whether the vessel propulsion apparatus **3** is used according to normal or reverse rotation specifications. If the rotation direction of the cam **51** is constant, the moving direction of the slider **49** is inverted between a case in which the pin portion **56** is inserted in the annular groove **57** at the right of the slider **49** and a case in which the pin portion **56** is inserted in the annular groove **57** at the left of the slider **49**. Therefore, the direction in which the slider **49** moves when a shift operation is performed is set according to the insertion position of the pin portion **56** with respect to the annular groove **57**.

In a case in which the vessel propulsion apparatus **3** is used according to normal rotation specifications, the pin portion **56** is inserted in the annular groove **57** at the position at which the slider **49** moves forwardly when a forward shift operation is performed. On the other hand, in a case in which the vessel propulsion apparatus **3** is used according to reverse rotation specifications, the pin portion **56** is inserted in the annular groove **57** at the position at which the slider **49** moves backwardly when a forward shift operation is performed. In other words, in a case in which the vessel propulsion apparatus **3** is used according to reverse rotation specifications, the pin portion **56** is inserted in the annular groove **57** at the position opposite to that of a case in which the vessel propulsion apparatus **3** is used according to normal rotation specifications. The specifications of the vessel propulsion apparatus **3** are set according to a method of assembling the vessel propulsion apparatus **3** as mentioned above (i.e., according to a direction in which the cam **51** is fitted), and therefore, even if the vessel propulsion apparatus **3** is used according to either of the specifications, the vessel operator can switch the traveling direction of the vessel **1** to the forward traveling by the same operation, and can switch the traveling direction thereof to the backward traveling by the same operation.

FIG. **7** is a view for describing a preload applied onto the first tapered roller bearing **32** and onto the second tapered roller bearing **35** according to the first preferred embodiment of the present invention.

The outboard motor **8** includes an adjusting member **58** arranged to apply a preload onto the first tapered roller bearing **32** and onto the second tapered roller bearing **35**. The adjusting member **58** is disposed between the second gear **25** and the propeller shaft **15**. The adjusting member **58** is, for example, annular. The adjusting member **58** includes, for example, a washer. The adjusting member **58** may include a plurality of members (e.g., a shim and a washer). The adjusting member **58** may be integrally provided with the propeller shaft or with the tapered roller bearing, for example, by molding. The adjusting member **58** surrounds the propeller shaft **15**. The propeller shaft **15** includes an annular flange **59** disposed between the first tapered roller bearing **32** and the second tapered roller bearing **35**. The flange **59** protrudes outwardly from the propeller shaft **15**, and extends in a circumferential direction of the propeller shaft **15** over the whole circumference. The flange **59** is disposed between the dog clutch **26** and the second tapered roller bearing **35**. The adjusting member **58** is disposed between the flange **59** and the second tapered roller bearing **35**. The adjusting member **58** is in contact with the flange **59** and with the second tapered roller bearing **35**. The adjusting member **58** and the flange **59** are disposed inside the second gear **25**. A member having a thickness slightly greater than the gap between the flange **59** and the second tapered roller bearing **35** is used as the adjusting member **58** in order to apply a preload. The adjusting member **58** is preferably made of, for example, carbon tool steel.

The adjusting member **58** is disposed between the second inner race **42** and the flange **59**, and therefore the propeller shaft **15** is disposed more forwardly with respect to the second tapered roller bearing **35** than in a case in which the adjusting member **58** is not disposed. Therefore, the first inner race **38** is pushed forwardly by the propeller shaft **15**, and a preload is applied onto the first tapered roller bearing **32** (see the white arrow). Additionally, the first inner race **38** is pushed forwardly, and, as a result, the first gear **24** holding the first tapered roller bearing **32** is pushed forwardly, and the tooth portion **28** of the first gear **24** is pressed against the first thrust bearing **31**. An internal gap of the first tapered roller bearing **32** is removed by a preload onto the first tapered roller bearing **32**, and the first tapered roller bearing **32** is restrained from being inclined and being moved in the axial direction. In other words, a preload applied onto the first tapered roller bearing **32** restrains the displacement of the first tapered roller bearing **32** and the first gear **24**.

On the other hand, the propeller shaft **15** pushes the first tapered roller bearing **32** forwardly, and, as a result, a backward reaction force is applied to the propeller shaft **15**, and is then transmitted to the second inner race **42** via the flange **59** and the adjusting member **58**. As a result, the second inner race **42** is pushed backwardly, and a preload is applied onto the second tapered roller bearing **35** (see the white arrow). Additionally, the second inner race **42** is pushed backwardly, and, as a result, the second gear **25** holding the second tapered roller bearing **35** is pushed backwardly, and the tooth portion **28** of the second gear **25** is pressed against the second thrust bearing **34**. An internal gap of the second tapered roller bearing **35** is removed by the preload onto the second tapered roller bearing **35**, and the second tapered roller bearing **35** is restrained from being inclined and being moved in the axial direction. In other words, the preload onto the second tapered roller bearing **35** makes it possible to restrain the second tapered roller bearing **35** and the second gear **25** from being displaced.

Next, a description will be given of a case in which the vessel propulsion apparatus **3** is used according to normal rotation specifications and a case in which the vessel propulsion apparatus **3** is used according to reverse rotation specifications.

FIGS. **8** to **11** are sectional views of the lower unit of the outboard motor **8** according to the first preferred embodiment of the present invention. The vessel propulsion apparatus **3** shown in FIGS. **8** and **9** is set at normal rotation specifications, whereas the vessel propulsion apparatus **3** shown in FIGS. **10** and **11** is set at reverse rotation specifications. In detail, the pin portion **56** is inserted in the annular groove **57** at the right of the slider **49** (i.e., innermost side of the figure sheet) in FIGS. **8** and **9**, whereas the pin portion **56** is inserted in the annular groove **57** at the left of the slider **49** (i.e., near side of the figure sheet) in FIGS. **10** and **11**.

As shown in FIG. **8**, when the vessel propulsion apparatus **3** set at normal rotation specifications generates a thrust in the forward direction, the dog clutch **26** is engaged with the first gear **24** serving as a forward gear (see the black arrow). As a result, the rotation of the drive shaft **14** is transmitted to the dog clutch **26** via the pinion **23** and the first gear **24**, and the normal-rotation propeller **7*a*** (see FIG. **1**) rotates in the normal rotation direction together with the dog clutch **26** and the propeller shaft **15**. A thrust in the forward direction generated by the rotation in the normal rotation direction of the propeller **7** is transmitted to the propeller shaft **15**, the first tapered roller bearing **32**, the washer **60**, the circlip **41**, the first gear **24**, the first thrust bearing **31**, the adaptor **36**, and the lower case **19** in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion **23** to the first gear **24** is applied to the first gear **24** at an engagement position of the pinion **23** and the first gear **24** (see the crosshatched arrow). In other words, a force by which the first gear **24** is inclined is applied to the first gear **24**. However, a thrust in the forward direction is applied to the first tapered roller bearing **32**, and, in addition, a preload is applied onto the first tapered roller bearing **32** and the first gear, and therefore the position of the first gear **24** is fixed. Therefore, the amount of inclination of the first gear **24** is minimized. Therefore, the engagement between the pinion **23** and the first gear **24** becomes stable, and a force greater than a designed, assumed value is prevented from being applied to the first gear **24**.

As shown in FIG. **9**, when the vessel propulsion apparatus **3** set at normal rotation specifications generates a thrust in the backward direction, the dog clutch **26** is engaged with the second gear **25** serving as a reverse gear (see the black arrow). As a result, the rotation of the drive shaft **14** is transmitted to the dog clutch **26** via the pinion **23** and the second gear **25**, and the normal-rotation propeller **7***a* (see FIG. **1**) rotates in the reverse rotation direction together with the dog clutch **26** and the propeller shaft **15**. A thrust in the backward direction generated by the rotation in the reverse rotation direction of the propeller **7** is transmitted to the propeller shaft **15**, the adjusting member **58**, the second tapered roller bearing **35**, the washer **61**, the circlip **45**, the second gear **25**, the second thrust bearing **34**, the housing **37**, and the lower case **19** in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of the rotation from the pinion **23** to the second gear **25** is applied to the second gear **25** at an engagement position of the pinion **23** and the second gear **25** (see the crosshatched arrow). However, when the vessel travels backwardly, torque transmitted from the pinion **23** to the second gear **25** is smaller than when the vessel travels forwardly, and therefore a reaction force applied to the second gear **25**, which is caused by the transmission of power from the pinion **23** to the second gear **25**, is also smaller. Additionally, a preload is applied onto the second tapered roller bearing **35** and the second gear **25**. Therefore, the amount of inclination of the second gear **25** is smaller than when the vessel travels forwardly.

As shown in FIG. **10**, when the vessel propulsion apparatus **3** set at reverse rotation specifications generates a thrust in the forward direction, the dog clutch **26** is engaged with the second gear **25** serving as a forward gear (see the black arrow). As a result, the rotation of the drive shaft **14** is transmitted to the dog clutch **26** via the pinion **23** and the second gear **25**, and the reverse-rotation propeller **7***b* (see FIG. **1**) rotates in the reverse rotation direction together with the dog clutch **26** and the propeller shaft **15**. A thrust in the forward direction generated by the rotation in the reverse rotation direction of the propeller **7** is transmitted to the propeller shaft **15**, the first tapered roller bearing **32**, the washer **60**, the circlip **41**, the first gear **24**, the first thrust bearing **31**, the adaptor **36**, and the lower case **19** in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion **23** to the second gear **25** is applied to the second gear **25** (see the crosshatched arrow). As a result, a force by which the second gear **25** is inclined is applied to the second gear **25**. However, a preload is applied onto the second tapered roller bearing **35** and the second gear **25**, and therefore the amount of inclination of the second gear **25** is restrained even if the reaction force is applied to the second gear **25**. Therefore, the engagement between the pinion **23** and the second gear **25** becomes stable, and a force greater than a designed, assumed value is prevented from being applied to the second gear **25**.

As shown in FIG. **11**, when the vessel propulsion apparatus **3** set at reverse rotation specifications generates a thrust in the backward direction, the dog clutch **26** is engaged with the first gear **24** serving as a reverse gear (see the black arrow). As a result, the rotation of the drive shaft **14** is transmitted to the dog clutch **26** via the pinion **23** and the first gear **24**, and the reverse-rotation propeller **7***b* (see FIG. **1**) rotates in the normal rotation direction together with the dog clutch **26** and the propeller shaft **15**. A thrust in the backward direction generated by the rotation in the normal rotation direction of the propeller **7** is transmitted to the propeller shaft **15**, the adjusting member **58**, the second tapered roller bearing **35**, the washer **61**, the circlip **45**, the second gear **25**, the second thrust bearing **34**, the housing **37**, and the lower case **19** in this order (see the white arrow). On the other hand, a reaction force caused by the transmission of power from the pinion **23** to the first gear **24** is applied to the first gear **24** at an engagement position of the pinion **23** and the first gear **24** (see the crosshatched arrow). However, a preload is applied onto the first tapered roller bearing **32** and the first gear **24**, and the reaction force applied to the first gear **24** when the vessel travels backwardly is small, and therefore the amount of inclination of the first gear **24** is smaller than when the vessel travels forwardly.

As described above, in the first preferred embodiment, the adjusting member **58** is arranged to apply a preload onto the first and second tapered roller bearings **32** and **35**, and the first gear **24** is pressed forwardly whereas the second gear **25** is pressed downwardly. As a result, an internal gap of the first tapered roller bearing **32** and that of the second tapered roller bearing **35** are removed, and the position of each of the first and second gears **24** and **25** is fixed. In other words, the first and second gears **24** and **25** are held so as not to perform an operation other than rotation. Therefore, the engagement between the pinion **23** and each gear (i.e., each of the first and second gears **24** and **25**) can be prevented from becoming unstable even when the vessel propulsion apparatus **3** is used according to either normal or reverse rotation specifications. This makes it possible to prevent the durability of the gears (i.e., the pinion **23**, the first gear **24**, and the second gear **25**) from being decreased. Therefore, the vessel propulsion apparatus **3** can be used according to either normal or reverse rotation specifications.

The position of each of the first and second gears **24** and **25** can be fixed, and the vessel propulsion apparatus **3** can be used according to either normal or reverse rotation specifications as described above, and therefore there is no need to provide special or unique components exclusively for each of the normal and reverse rotation specifications. Therefore, it is possible to reduce the production costs and the number of development man-hours of the vessel propulsion apparatus **3**. Additionally, the retail outlet of the vessel propulsion apparatus **3** has no need to stock special or unique components as spare components used for repairs for each of the normal and reverse rotation specifications. Still additionally, the first tapered roller bearing **32**, the second tapered roller bearing **35**, the first gear **24**, and the second gear **25** can remove their backlashes by applying a preload onto the first and second tapered roller bearings **32** and **35**, and therefore it is possible to prevent the occurrence of an abnormal noise caused by these backlashes.

Additionally, the vessel **1** usually travels forwardly more often than backwardly. Therefore, in the vessel propulsion apparatus **3** used according to normal rotation specifications, the number of times of use of the first gear **24** serving as a forward gear (e.g., the number of times of connection to the dog clutch **26**) is greater than the number of times of use of the second gear **25** serving as a reverse gear. On the other hand, in the vessel propulsion apparatus **3** used according to reverse rotation specifications, the number of times of use of the second gear **25** serving as a forward gear is greater than the number of times of use of the first gear **24** serving as a reverse gear. Therefore, the first gear **24** is more easily worn out than the second gear **25** in the vessel propulsion apparatus **3** used according to normal rotation specifications, whereas the second gear **25** is more easily worn out than the first gear **24** in the vessel propulsion apparatus **3** used according to reverse rotation specifications.

Thus, in the vessel propulsion apparatus **3**, the gear (one of the first and second gears **24** and **25**) used as a forward gear is worn out more easily. Therefore, if the two first gears **24** are replaced with each other between the two vessel propulsion apparatuses **3** used according to the mutually different specifications and if the two second gears **25** are replaced with each other therebetween, the gear used as a forward gear is used as a reverse gear, and the gear used as a reverse gear is used as a forward gear. As a result, the first and second gears **24** and **25** can be used and worn evenly, and therefore the product life of the vessel propulsion apparatus **3** can be lengthened. Additionally, if the same vessel propulsion apparatus **3** is used according to one of the two different kinds of specifications and is then used according to the other one, the first and second gears **24** and **25** can be used and worn evenly. Therefore, the product life of the vessel propulsion apparatus **3** can be lengthened.

Additionally, in the first preferred embodiment, the lower case **19** defines the internal space **21** in which the gear mechanism **20** is contained and the opening **22** connected to the internal space **21**. The gear mechanism **20** and the housing **37** are built into the internal space **21** from the opening **22**. The second gear **25** is disposed between the opening **22** and the first gear **24**. In other words, the second gear **25** is disposed closer to the opening **22** than the first gear **24**. In the production process of the vessel propulsion apparatus **3**, there is a possibility that the adjusting member **58** that has already been built in the lower case **19** will be detached and replaced with another adjusting member **58** having a different thickness, for example, when the vessel propulsion apparatus **3** does not satisfy a predetermined performance. For example, when the adjusting member **58** is disposed between the first gear **24** and the propeller shaft **15**, there is a need to detach a plurality of components including the housing **37**, the second gear **25**, and the pinion **23** from the lower case **19** through the opening **22** in order to change the adjusting member **58**. On the other hand, the second gear **25** is disposed closer to the opening **22** than the first gear **24**, and therefore the number of components to be detached from the lower case **19** in order to change the adjusting member **58** is small when the adjusting member **58** is disposed between the second gear **25** and the propeller shaft **15**. Therefore, the number of man-hours relative to the change of the adjusting member **58** can be decreased by disposing the adjusting member **58** between the second gear **25** and the propeller shaft **15**.

Additionally, in the first preferred embodiment, the first and second gears **24** and **25** preferably are the same type of gear, and are the same in shape. Therefore, the kinds of components used in the vessel propulsion apparatus **3** can be decreased. As a result, the production costs and the number of development man-hours of the vessel propulsion apparatus **3** can be reduced. Additionally, the first and second gears **24** and **25** are the same in shape, and therefore the first and second gears **24** and **25** can be used and worn evenly by replacing the first and second gears **24** and **25** with each other in the same vessel propulsion apparatus **3** after this vessel propulsion apparatus **3** has been used during a fixed period of time. As a result, the product life of the vessel propulsion apparatus **3** can be lengthened.

Other Preferred Embodiments

Although the first preferred embodiment of the present invention has been described above, the present invention is not limited to the contents of the first preferred embodiment, and can be variously modified within the scope of the appended claims.

For example, in the first preferred embodiment, the vessel **1** is preferably provided with the two vessel propulsion apparatuses **3** as described above. However, the number of vessel propulsion apparatuses **3** of the vessel **1** is not limited to two, and may be one or may be three or more.

Additionally, in the first preferred embodiment, the adjusting member **58** is preferably disposed between the second gear **25** and the propeller shaft **15** as described above. However, the adjusting member **58** may be disposed between the first gear **24** and the propeller shaft **15**.

Additionally, in the first preferred embodiment, the first and second gears **24** and **25** preferably are the same in shape as described above. However, the first and second gears **24** and **25** may have mutually different shapes.

Additionally, in the first preferred embodiment, each of the pinion **23**, the first gear **24**, and the second gear **25** preferably is a bevel gear as described above. However, the pinion **23** may be a gear other than the bevel gear. The same applies to the first and second gears **24** and **25**.

Additionally, as described above, in the first preferred embodiment, the first and second roller bearings **30** and **33** preferably are the same type of bearing, whereas the first and second thrust bearings **31** and **34** are the same type of bearing. However, the first and second roller bearings **30** and **33** may have mutually different shapes. The same applies to the first and second thrust bearings **31** and **34**.

Additionally, in the first preferred embodiment, each of the first bearing (the first tapered roller bearing **32**) supporting the first gear **24** and the second bearing (the second tapered roller bearing **35**) supporting the second gear **25** preferably is a tapered roller bearing as described above. However, without being limited to the tapered roller bearing, each of the bearings **32** and **35** may be another type of bearing such as a ball bearing. The same applies to the bearings **30**, **31**, **33**, and **34** other than the bearings **32** and **35**.

Additionally, in the first preferred embodiment, the vessel propulsion apparatus **3** preferably includes the outboard motor **8** as described above. However, the vessel propulsion apparatus **3** may be an inboard-outboard motor. In other words, the vessel propulsion apparatus **3** may be arranged to include an engine disposed inside the vessel and a propulsion unit disposed outside the vessel and to generate a thrust by driving the propulsion unit via the engine. If so, the first and second gears **24** and **25** may be arranged to be disposed in the propulsion unit, and the adjusting member **58** may be arranged to apply a preload onto the first bearing supporting the first gear **24** and onto the second bearing supporting the second gear **25**.

Additionally, in the first preferred embodiment, the insertion position of the pin portion **56** with respect to the annular groove **57** is preferably changed by whether the vessel propulsion apparatus **3** is used according to normal or reverse rotation specifications as described above (see FIG. **3**). However, the insertion position of the pin portion **56** with respect to the annular groove **57** may be fixed, and the rotation direction of the cam **51** by the shift actuator **52** (see FIG. **3**) may be changed by whether the vessel propulsion apparatus **3** is used according to normal or reverse rotation specifications. In other words, in Drive-By-Wire (DBW), the specifications of the vessel propulsion apparatus **3** may be changed by controlling a direction in which the shift actuator **52**(electric actuator) is operated.

In detail, if the rotation direction of the cam **51** is fixed, the moving direction of the dog clutch **26** is changed by the insertion position of the pin portion **56** with respect to the annular groove **57**. On the other hand, the moving direction of the dog clutch **26** is reversed if the rotation direction of the cam **51** is reversed even when the insertion position of the pin portion **56** with respect to the annular groove **57** is fixed. Therefore, the specifications of the vessel propulsion apparatus **3** may be set by the rotation direction of the cam **51** by the shift actuator **52**. In other words, when the vessel propulsion apparatus **3** is used according to reverse rotation specifications, the cam **51** may be rotationally driven in a direction opposite to the direction given when the vessel propulsion apparatus **3** is used according to normal rotation specifications. If so, a method of assembling the vessel propulsion apparatus **3** (i.e., a direction in which the cam **51** is fitted) is not necessarily required to be changed for each of the normal and reverse rotation specifications.

The present application corresponds to Japanese Patent Application No. 2011-051668 filed on Mar. 9, 2011 in the Japan Patent Office, the entire disclosure of which is incorporated herein by reference.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A vessel propulsion apparatus comprising:

a first shaft that is rotationally driven;

a drive gear connected to the first shaft;

a tubular first driven gear that is disposed forward relative to the first shaft and engages the drive gear;

a tubular second driven gear that is disposed rearward relative to the first shaft and engages the drive gear;

a dog clutch that is switched by a shift operation between a connected state in which the dog clutch is connected to one of the first driven gear and the second driven gear and a non-connected state in which the dog clutch is not connected to either of the first driven gear and the second driven gear;

a second shaft that is inserted in the first driven gear and in the second driven gear and connected to the dog clutch;

a bearing disposed between an inner surface of the second driven gear and an outer surface of the second shaft; wherein

the second driven gear is pressed backwardly by a preload onto the bearing.

2. The vessel propulsion apparatus according to claim **1**, wherein the vessel propulsion apparatus has a reverse rotation specification that generates a thrust in a forward direction when the dog clutch is engaged with the second driven gear.

3. The vessel propulsion apparatus according to claim **1**, further comprising an adjusting member that applies the preload onto the bearing.

4. The vessel propulsion apparatus according to claim **3**, wherein the adjusting member is a shim having an annular shape or a washer having an annular shape.

5. The vessel propulsion apparatus according to claim **3**, wherein the second shaft includes an annular flange that protrudes outwardly from the outer surface of the second shaft;

the flange is disposed between the dog clutch and the bearing; and

the adjusting member is disposed between the flange and the bearing.

6. The vessel propulsion apparatus according to claim **1**, wherein the bearing is a tapered roller bearing.

7. The vessel propulsion apparatus according to claim **6**, wherein the tapered roller bearing includes a cylindrical inner race, a cylindrical outer race, and a plurality of rollers disposed between the inner race and the outer race; and

the plurality of rollers are disposed along a conic surface that tapers toward a rear of the vessel propulsion apparatus.

8. The vessel propulsion apparatus according to claim **6**, wherein the tapered roller bearing includes a cylindrical inner race, a cylindrical outer race, and a plurality of rollers disposed between the inner race and the outer race; and

the adjusting member is disposed between the inner race and the flange.

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