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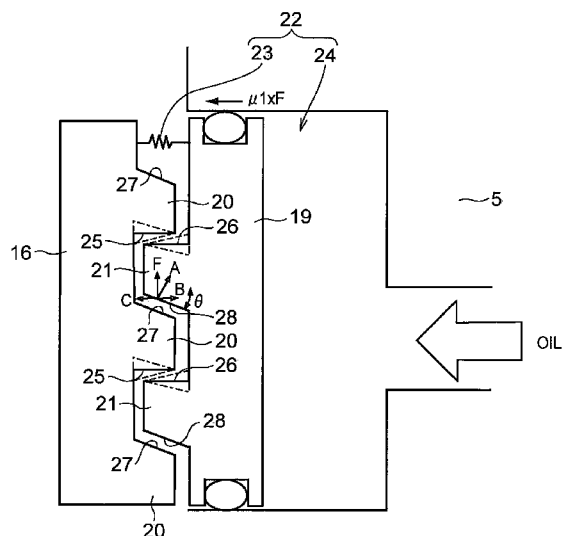
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(54) Title: AUTOMATIC TRANSMISSION

FIG. 1

(57) **Abstract:** An automatic transmission includes a first engagement mechanism (B2) and an electronic control unit. The first engagement mechanism includes a first member (16), a second member (19), and a pressing mechanism 22-24). The electronic control unit is configured to control the first engagement mechanism to be engaged when a first transmission stage is selected. The electronic control unit is configured to control the first engagement mechanism to be released when a second transmission stage is selected. First tooth surfaces (27) and third tooth surfaces (28) include inclined surfaces such that a thrust for separating the first member and the second member from each other in an axial direction is generated in accordance with a torque in a direction in which the first tooth surfaces and the third tooth surfaces are brought into contact with each other during shifting from the first transmission stage to the second transmission stage.



AUTOMATIC TRANSMISSION

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to an automatic transmission that is provided with an engagement mechanism which sets a predetermined transmission stage by being engaged or released.

10 2. Description of Related Art

[0002] Japanese Patent Application Publication No. 2009-063120 (JP 2009-063120 A) discloses an automatic transmission that is capable of setting a forward first speed to a forward sixth speed and a reverse first speed. This automatic transmission is provided with two planetary gear mechanisms and a plurality of engagement
15 mechanisms that connect rotating elements of the planetary gear mechanisms to each other or stop any of the rotating elements. One of these engagement mechanisms is a one-way clutch that is configured to function as a brake, and the forward first speed is set when this engagement mechanism is engaged. When engine brake acts, a torque in the direction opposite to a direction during forward traveling is applied to this one-way clutch. In this
20 automatic transmission, the rotating element that is stopped by the engagement of the one-way clutch is configured to be also stopped when the reverse first speed is set, and thus the one-way clutch is released when reverse traveling is performed and the engine brake acts. Accordingly, a friction clutch is disposed in parallel to the one-way clutch in this automatic transmission, and this automatic transmission is configured for the friction
25 clutch to be engaged when the reverse traveling is performed and the engine brake acts. As this friction clutch, a multi-plate clutch is adopted that is configured to have a plurality of alternately arranged friction plates, in which the friction materials thereof are in contact with each other for connection allowing torque transmission.

[0003] In addition, International Publication No. 2013/076827 discloses an

automatic transmission in which a toothed brake is disposed so that one of rotating elements of a planetary gear mechanism can be selectively engaged with a fixed portion such as a housing. The toothed brake has a structure of a dog clutch. As this toothed brake, a normally closed brake is used that is configured to control engagement and release
5 by using a hydraulic actuator and is configured to be engaged when hydraulic pressure supply to the hydraulic actuator is stopped.

[0004] In addition, Japanese Utility Model Application Publication No. 2-21336 (JP 2-21336 U) discloses the shape of a dog clutch that is used in a machine tool. In this dog clutch, one tooth surfaces of dog teeth are formed at an angle to a central axial
10 direction so that backlash is suppressed and poor meshing attributable to contact between tooth tips is suppressed when the dog teeth mesh. More specifically, this dog clutch is used at a part that rotates in only one direction and is shaped so that meshing is completed based on the relative rotation of the dog teeth along inclined surfaces even in a case where the tooth tips are brought into contact with each other during a meshing operation.

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SUMMARY OF THE INVENTION

[0005] The toothed engagement mechanism disclosed in International Publication No. 2013/076827 and JP 2-21336 U can be applied to the automatic transmission disclosed in JP 2009-063120 A. This toothed engagement mechanism, however, is subjected to a
20 frictional force on the tooth surfaces of the dog teeth when a torque acts on the dog teeth. When the torque acts on the dog teeth, it is difficult to release the toothed engagement mechanism, and thus the toothed engagement mechanism is released after the torque acting on the dog teeth is reduced in most cases. In order to release the toothed engagement mechanism after the torque acting on the dog teeth is reduced as described above, control
25 for reducing the torque acting on the dog teeth has to be coordinated with control for releasing the toothed engagement mechanism. Accordingly, complexity may be added to the control that is performed during the release of the toothed engagement mechanism.

[0006] The invention provides an automatic transmission that is capable of simplifying control which is performed during shifting based on the release of a toothed

engagement mechanism.

[0007] An automatic transmission according to an aspect of the invention includes a first engagement mechanism and an electronic control unit. The first engagement mechanism includes a first member, a second member, and a pressing
5 mechanism. The first member includes first dog teeth. The second member includes second dog teeth meshing with the first dog teeth when the second member is moved in an axial direction. The first dog teeth include first tooth surfaces directed to one side in a circumferential direction and second tooth surfaces directed to the other side in the circumferential direction. The second dog teeth include third tooth surfaces facing the
10 first tooth surfaces and fourth tooth surfaces facing the second tooth surfaces. The pressing mechanism is configured to press the second member to the first member side so as to maintain a state where the first tooth surfaces and the third tooth surfaces are in contact with each other. The electronic control unit is configured to control the first engagement mechanism to be engaged when a first transmission stage is selected among a
15 plurality of transmission stages of the automatic transmission. The electronic control unit is configured to control the first engagement mechanism to be released when a second transmission stage is selected among the plurality of transmission stages of the automatic transmission. The first tooth surfaces and the third tooth surfaces include inclined surfaces such that a thrust for separating the first member and the second member from
20 each other in the axial direction is generated in accordance with a torque in a direction in which the first tooth surfaces and the third tooth surfaces are brought into contact with each other during shifting from the first transmission stage to the second transmission stage.

[0008] In the automatic transmission according to the aspect described above, the
25 first transmission stage may be any one of a plurality of forward transmission stages of the automatic transmission. The electronic control unit may be configured to control the first engagement mechanism to be engaged when the first transmission stage or a reverse transmission stage is selected. The first engagement mechanism may be configured to transmit a torque by the second tooth surfaces and the fourth tooth surfaces being in

contact with each other when the first transmission stage is selected. The first engagement mechanism may be configured to transmit a torque by the first tooth surfaces and the third tooth surfaces being in contact with each other when the reverse transmission stage is selected.

5 **[0009]** In the automatic transmission according to the aspect described above, the electronic control unit may be configured to control the pressing mechanism so that the second member is pressed to the first member side when engine brake acts or when the reverse transmission stage is selected while the first transmission stage is selected.

10 **[0010]** In the automatic transmission according to the aspect described above, the pressing mechanism may include an elastic body and an actuator. The elastic body may be configured to press the second member to one side in the axial direction. The actuator may be configured to generate a load against a load with which the second member is pressed by the elastic body.

15 **[0011]** In the automatic transmission according to the aspect described above, the actuator may be configured to generate a load corresponding to a supplied hydraulic pressure.

[0012] In the automatic transmission according to the aspect described above, the actuator may be configured to generate a load corresponding to an amount of a current with which the actuator is energized.

20 **[0013]** In the automatic transmission according to the aspect described above, the elastic body may be configured to exert an elastic force in a direction in which the second member is separated from the first member. The second tooth surfaces and the fourth tooth surfaces may include inclined surfaces inclined with respect to directions of rotation of the first member and the second member such that the second member is not separated
25 from the first member by the elastic force of the elastic body when the second tooth surfaces and the fourth tooth surfaces are in contact with each other and when the actuator generates no load.

[0014] The automatic transmission according to the aspect described above may further include a second engagement mechanism. The second engagement mechanism

may be configured to connect a third member and a fourth member disposed to be capable of relative rotation to each other so as to transmit a torque between the third member and the fourth member. The electronic control unit may be configured to control the first engagement mechanism to be engaged and control the second engagement mechanism to be released when the first transmission stage is selected. The electronic control unit may be configured to control the first engagement mechanism to be released and control the second engagement mechanism to be engaged when the second transmission stage is selected.

[0015] In the automatic transmission according to the aspect described above, the second engagement mechanism may be configured to change a capacity of the torque transmitted between the third member and the fourth member. The first engagement mechanism may be configured for the direction of a torque acting on the first member or the second member to be gradually reversed in response to an increase in the capacity of the torque.

[0016] In the automatic transmission according to the aspect described above, the first engagement mechanism may be a toothed brake.

[0017] In the automatic transmission according to the aspect described above, the first member and the second member may be configured to rotate relative to each other. The first engagement mechanism may be a clutch mechanism connecting the first member and the second member to each other for integral rotation when the respective dog teeth mesh with each other.

[0018] The automatic transmission according to the aspect described above may further include a third engagement mechanism. The electronic control unit may be configured to allow the third engagement mechanism to be engaged when the first transmission stage is selected or when the second transmission stage is selected.

[0019] The automatic transmission according to the aspect described above may further include a first planetary gear mechanism and a second planetary gear mechanism. The first planetary gear mechanism may include three rotating elements. The second planetary gear mechanism may include three rotating elements. The first engagement

mechanism or the second engagement mechanism or the third engagement mechanism may be configured to connect any of the rotating elements of the first planetary gear mechanism or the second planetary gear mechanism to each other or fix any of the rotating elements.

[0020] The automatic transmission according to the aspect described above is configured for the first transmission stage to be selected when the first member and the second member mesh with each other and for the meshing to be released when the second transmission stage is selected. In addition, the inclined surfaces facing each other are formed in the first dog teeth and the second dog teeth, and the first member and the second member are configured to be separated from each other in the axial direction in accordance with the torque in the direction in which these inclined surfaces are brought into contact with each other. Accordingly, the shifting from the first transmission stage to the second transmission stage can be performed by just controlling the torque transmitted to the first engagement mechanism so that the torque in the direction in which the inclined surfaces of the respective dog teeth are brought into contact with each other acts. Accordingly, control for the shifting as described above can be simplified. In addition, the pressing mechanism pressing the second member to the first member side so as to maintain the state where the first tooth surfaces and the third tooth surface are in contact with each other is provided, and thus a state where the first engagement mechanism is engaged can be maintained, regardless of the direction of the torque transmitted to the first engagement mechanism, when the pressing mechanism is controlled. In other words, another device maintaining the state where the first member and the second member are engaged with each other does not have to be disposed when the torque transmitted to the first engagement mechanism is reversed for the contact between the first tooth surfaces and the third tooth surfaces. As a result, an increase in the size of the transmission can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the

accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic diagram for showing an example of the configuration of a first engagement mechanism according to the invention;

FIG. 2 is a schematic diagram for showing an example configured to exert a thrust
5 onto a piston by using an electromagnetic actuator;

FIG. 3 is a schematic diagram for showing an example configured to cause dog teeth to be engaged or released via a shift fork;

FIG. 4 is a schematic diagram for showing an example configured to exert a thrust onto the piston by using a ball cam mechanism;

10 FIG. 5 is a flowchart for showing an example of pressing mechanism control according to the invention;

FIG. 6 is a skeleton diagram illustrating an example of the configuration of a transmission that is provided with the first engagement mechanism according to the invention;

15 FIG. 7 is an engagement table illustrating which engagement mechanism is engaged when each transmission stage is set;

FIG. 8 is a nomogram illustrating the operation state of each rotating element of the transmission;

20 FIG. 9 is a skeleton diagram illustrating another configuration example of the transmission that is provided with the first engagement mechanism according to the invention;

FIG. 10 is an engagement table illustrating which engagement mechanism is engaged when each transmission stage of the transmission is set; and

25 FIG. 11 is a nomogram illustrating the operation state of each rotating element of the transmission.

DETAILED DESCRIPTION OF EMBODIMENTS

[0022] An automatic transmission according to the invention, which is provided with a first engagement mechanism that has two members meshing with each other, is

configured to perform shifting from a first transmission stage that is set when the first engagement mechanism is engaged to a second transmission stage that is set when the first engagement mechanism is released. FIG. 6 illustrates an example of the configuration of the automatic transmission that has the above-described configuration. The automatic transmission that is illustrated in FIG. 6, which is mounted on a vehicle, has a known double pinion-type planetary gear mechanism (hereinafter, referred to as a first planetary gear mechanism 1) and a Ravigneaux-type planetary gear mechanism (hereinafter, referred to as a second planetary gear mechanism 2). This automatic transmission is connected to an output shaft 4 of an engine 3, which is a driving force source, via a torque converter (not illustrated) and is configured to output a torque after changing an input torque and a rotation speed. More specifically, this automatic transmission is configured to be capable of setting transmission stages of a forward first speed to a forward eighth speed and transmission stages of a reverse first speed and a reverse second speed and is configured to set any of the transmission stages in accordance with a target rotation speed of the engine 3, a required driving force, and the like.

[0023] The configuration of the automatic transmission that is illustrated in FIG. 6 will be described in detail. A first sun gear 6 that is connected to a fixed portion 5 such as a housing, a first inner pinion gear 7 that meshes with the first sun gear 6, a first outer pinion gear 8 that meshes with the first inner pinion gear 7, a first ring gear 9 that meshes with the first outer pinion gear 8, and a first carrier 11 that holds the first inner pinion gear 7 and the first outer pinion gear 8 to be capable of rotation and revolution and is connected to an input shaft 10 constitute the first planetary gear mechanism 1. In other words, the first planetary gear mechanism 1 is a differential mechanism that has three rotating elements and is configured for the first carrier 11 to function as an input element, for the first sun gear 6 to function as a reaction force element, and for the first ring gear 9 to function as an output element when the engine 3 outputs a driving force. In addition, the first planetary gear mechanism 1 functions as a decelerator.

[0024] A second sun gear 12 and a third sun gear 13 that are concentrically arranged with the input shaft 10, a second inner pinion gear 14 that meshes with the third

sun gear 13, a second outer pinion gear 15 that meshes with the second inner pinion gear 14 and the second sun gear 12, a second carrier 16 that holds the second inner pinion gear 14 and the second outer pinion gear 15 to be capable of rotation and revolution, and a second ring gear 17 that meshes with the second outer pinion gear 15 constitute the second planetary gear mechanism 2 that is illustrated in FIG. 6. In other words, a single pinion-type planetary gear mechanism and a double pinion-type planetary gear mechanism having both the second carrier 16 and the second ring gear 17 constitute the second planetary gear mechanism 2. Accordingly, the second planetary gear mechanism 2 is configured as a differential mechanism that has the four rotating elements of the second sun gear 12, the third sun gear 13, the second carrier 16, and the second ring gear 17.

[0025] A plurality of clutches for selective engagement between the respective rotating elements of the first planetary gear mechanism 1 described above and the respective rotating elements of the second planetary gear mechanism 2 and a brake for stopping any of the rotating elements are additionally disposed. Specifically, a first clutch C1 is disposed to connect the first ring gear 9 and the third sun gear 13 to each other, a second clutch C2 is disposed to connect the input shaft 10 or the first carrier 11 and the second carrier 16 to each other, a third clutch C3 is disposed to connect the first ring gear 9 and the second sun gear 12 to each other, and a fourth clutch C4 is disposed to connect the first carrier 11 and the second sun gear 12 to each other. Each of the clutches C1, C2, C3, C4 is configured to be capable of changing the transmission torque capacity based on the amount of the control of a hydraulic actuator, an electromagnetic actuator, or the like. In the following description, a friction clutch that is configured to be capable of transmitting the torque by using a frictional force and changing the transmission torque capacity in accordance with the hydraulic pressure which is supplied to the hydraulic actuator will be described as an example.

[0026] In addition, a first brake B1 is disposed to stop the second sun gear 12 by connecting the fixed portion 5 such as the housing and the second sun gear 12 to each other. Likewise, a second brake B2 is disposed to stop the second carrier 16 by connecting the fixed portion 5 and the second carrier 16 to each other. In the example that is illustrated

in FIG. 6, a friction brake that is capable of controlling a braking force which acts on the second sun gear 12 by changing the frictional force, that is, by changing the transmission torque capacity, constitutes the first brake B1 and the second brake B2 is configured to stop the second carrier 16 when the second carrier 16 and the fixed portion 5 mesh with each other. The second brake B2 corresponds to the first engagement mechanism pertaining to the case of the implementation of the invention.

[0027] An electronic control unit (hereinafter, referred to as an ECU 18) is also disposed so as to control the engine 3, each of the engagement mechanisms, and the like. The ECU 18 is configured to have a microcomputer as a main component as is known, and is configured to determine a signal to be output to the engine 3 or the respective engagement mechanisms based on a signal that is input from a sensor (not illustrated), a pre-stored map, a pre-stored arithmetic expression, and the like and output the determined signal to the engine 3 or the respective engagement mechanisms. As an example thereof, signals of a vehicle speed that is detected by a vehicle speed sensor and an accelerator opening that is detected by an accelerator opening sensor are input into the ECU 18. As is known, a shift map that is prepared in advance by using the vehicle speed and the accelerator opening as parameters is stored in the ECU 18, and the transmission stage is selected by using the input signals and the shift map. Then, the ECU 18 outputs a control signal to the respective clutches and the respective brakes described above so that the transmission stage which is selected is attained. In this case, the transmission torque capacity of the friction clutch, the friction brake, or the like may be controlled in accordance with various conditions so as to, for example, suppress a shock that is caused when the transmission stage is changed.

[0028] The engagement table in FIG. 7 illustrates which engagement mechanism is engaged when each transmission stage is set. "o" in FIG. 7 represents a state where the clutch or the brake is engaged, and "-" in FIG. 7 represents a state where the clutch or the brake is released. As illustrated in FIG. 7, the forward first speed is set when the first clutch C1 and the second brake B2 are engaged, the forward second speed is set when the first clutch C1 and the first brake B1 are engaged, the forward third speed is set when the

first clutch C1 and the third clutch C3 are engaged, the forward fourth speed is set when the first clutch C1 and the fourth clutch C4 are engaged, the forward fifth speed is set when the first clutch C1 and the second clutch C2 are engaged, the forward sixth speed is set when the second clutch C2 and the fourth clutch C4 are engaged, the forward seventh speed is set when the second clutch C2 and the third clutch C3 are engaged, and the forward eighth speed is set when the second clutch C2 and the first brake B1 are engaged. In addition, the reverse first speed is set when the second brake B2 and the third clutch C3 are engaged and the reverse second speed is set when the second brake B2 and the fourth clutch C4 are engaged. The transmission ratio is "1" when the forward sixth speed is set, the transmission ratio exceeds "1" when any one of the transmission stages of the forward first speed to the forward fifth speed is set, and the transmission ratio is less than "1" when the forward seventh speed or the forward eighth speed is set. The forward first speed corresponds to the first transmission stage pertaining to the case of the implementation of the invention, the forward second speed corresponds to the second transmission stage pertaining to the case of the implementation of the invention, the first brake B1 corresponds to the second engagement mechanism pertaining to the case of the implementation of the invention, and the first clutch C1 corresponds to the third engagement mechanism pertaining to the case of the implementation of the invention. As described above, the ECU 18 controls each of the clutches and each of the brakes of the automatic transmission in accordance with the selected transmission stage. The first engagement mechanism, the second engagement mechanism, and the third engagement mechanism are included in these clutches and brakes.

[0029] FIG. 8 is a nomogram illustrating the operation state of each rotating element in the respective transmission stages. The vertical axis in FIG. 8 represents the rotation speed of each rotating element, and the rotation speed input into the transmission is illustrated as being constant. In the following description, a case where the direction of rotation of each rotating element is the same as the direction of rotation of the engine 3 will be referred to as positive rotation and a case where the direction of rotation of each rotating element is opposite to the direction of rotation of the engine 3 will be referred to as

negative rotation. In addition, a torque that acts to reduce the rotation speed during the negative rotation or a torque that acts to increase the rotation speed during the positive rotation will be referred to as a positive torque and a torque that acts to reduce the rotation speed during the positive rotation or a torque that acts to increase the rotation speed during the negative rotation will be referred to as a negative torque. Accordingly, in FIG. 8, the positive rotation is the side above “0”, the negative rotation is the side below “0”, the torque that acts in the upward direction with respect to each rotating element is the positive torque, and the torque that acts in the downward direction with respect to each rotating element is the negative torque.

[0030] As described above, the first planetary gear mechanism 1 is configured to function as the decelerator and is configured to amplify the torque that is transmitted from the engine 3 and then output the amplified torque from the first ring gear 9. In addition, the first clutch C1 is engaged at the forward first speed. In other words, the first ring gear 9 and the third sun gear 13 are connected to each other via the first clutch C1 as described above. Accordingly, the positive torque is input from the engine 3 to the third sun gear 13 via the first ring gear 9, and thus the third sun gear 13 functions as the input element of the second planetary gear mechanism 2. At the forward first speed, in addition, the second brake B2 is engaged to connect the second carrier 16 and the fixed portion 5 to each other, and thus the rotation speed of the second carrier 16 is maintained at “0”. Accordingly, the second carrier 16 functions as the reaction force element of the second planetary gear mechanism 2. As a result, the torque that is input into the transmission is amplified in accordance with the gear ratio of the transmission and then is output from the second ring gear 17. The negative torque is transmitted to the second carrier 16 while the driving force is output from the engine 3.

[0031] The first clutch C1 is engaged not only at the forward first speed but also at the forward second speed. Accordingly, the positive torque is input from the engine 3 to the third sun gear 13 via the first ring gear 9, and thus the third sun gear 13 functions as the input element of the second planetary gear mechanism 2. At the forward second speed, the first brake B1 is engaged to connect the second sun gear 12 and the fixed portion

5 to each other, and thus the rotation speed of the second sun gear 12 is maintained at "0". Accordingly, the second carrier 16 functions as the reaction force element of the second planetary gear mechanism 2. As a result, the torque that is input into the transmission is amplified in accordance with the gear ratio of the transmission and then is output from the second ring gear 17.

[0032] During the upshift to the forward second speed from the forward first speed set as described above, the second brake B2 is released and the first brake B1 is engaged. As described above, the second brake B2 is configured to transmit the torque by meshing. The brake that transmits the torque by meshing as described above cannot control the transmission torque capacity. Accordingly, a large amount of torque is applied to the second brake B2 and a large amount of frictional force acts on the meshing surface while the second carrier 16 is functioning as the reaction force element, and thus the second brake B2 becomes less likely to be released in some cases. Accordingly, this automatic transmission is configured for the torque that is applied to the second brake B2 to be reduced and for the second brake B2 to be released with the transmission torque capacity of the first brake B1 increased to be allowed to function as a reaction force at the forward first speed. In other words, this automatic transmission is configured for the negative torque that is applied to the second brake B2 to be reduced when the traveling is performed with the forward first speed set.

[0033] It is necessary to determine whether the second brake B2 is completely released and then increase the transmission torque capacity of the first brake B1 for the engagement of the first brake B1 in the case of a transition to the forward second speed by increasing the transmission torque capacity of the first brake B1 so as to suppress the application of the torque to the second brake B2, releasing the second brake B2 thereafter, and then increasing the transmission torque capacity of the first brake B1. When a sensor or the like is disposed so as to detect a complete release of the second brake B2, the device may become larger in size, or the shift response may be reduced due to a factor such as the waiting for the release of the second brake B2. In addition, the shift control may become complicated because coordination has to be performed between control for releasing the

second brake B2 and control for changing the transmission torque capacity of the first brake B1.

[0034] Accordingly, this automatic transmission is configured to allow the second brake B2 to be released by increasing the transmission torque capacity of the first brake B1 so that the positive torque is transmitted to the second carrier 16. FIG. 1 is a schematic diagram for showing the configuration of the second brake B2. The second brake B2 that is illustrated in FIG. 1 is configured for a piston 19, which is spline-engaged with the fixed portion 5, and the second carrier 16 to mesh with each other. Specifically, a side surface of the second carrier 16 and the piston 19 are disposed to face each other in an axial direction, a plurality of first dog teeth 20 that protrude in the axial direction are formed at predetermined intervals in a circumferential direction on the surface of the second carrier 16 facing the piston 19, and a plurality of second dog teeth 21 that protrude in the axial direction and mesh with the first dog teeth 20 are formed at predetermined intervals in the circumferential direction on the surface of the piston 19 facing the second carrier 16. As described above, the piston 19 is spline-engaged with the fixed portion 5. Accordingly, the piston 19 is capable of moving in the axial direction and is stopped in the direction of rotation. The piston 19 corresponds to the second member pertaining to the case of the implementation of the invention.

[0035] A pressing mechanism 22 is disposed so as to apply an axial pressing force to the piston 19. In the example that is illustrated in FIG. 1, a return spring 23 that exerts a load on the piston 19 so that the piston 19 is separated from the second carrier 16 and a hydraulic actuator 24 that is disposed on a back surface (surface on the side opposite to the surface facing the second carrier 16) side of the piston 19 so as to exert a pressing force against the spring force of the return spring 23 constitute the pressing mechanism 22. Accordingly, the piston 19 that is illustrated in FIG. 1 is configured to approach the second carrier 16 when the hydraulic pressure supplied to the hydraulic actuator 24 increases and, on the contrary, to be separated from the second carrier 16 by the spring force of the return spring 23 when the hydraulic pressure supplied to the hydraulic actuator 24 decreases. Also, the piston 19 that is illustrated in FIG. 1 may be configured for the spring force of the

return spring 23 to be exerted so that the piston 19 approaches the second carrier 16 and for the hydraulic actuator 24 to generate a load against the spring force, that is, a load separating the piston 19 from the second carrier 16.

[0036] The respective dog teeth 20, 21 that are illustrated in FIG. 1 are configured to be capable of reducing the hydraulic pressure supplied to the hydraulic actuator 24 when the forward first speed is set. Specifically, tooth surfaces of the respective dog teeth 20, 21 are formed so that a thrust for separation from the second carrier 16 is less likely to be generated in the piston 19 when the first dog teeth 20 and the second dog teeth 21 are in contact with each other. In the example that is illustrated in FIG. 1, the side surfaces of the dog teeth 20, 21 that are in contact with each other while the vehicle is traveling with the forward first speed set, that is, tooth surfaces 25, 26 where the first dog teeth 20 and the second dog teeth 21 face each other, are formed to be substantially orthogonal to the direction of rotation. The tooth surfaces 25 of the first dog teeth 20 that are in contact when the vehicle travels with the forward first speed set correspond to the second tooth surfaces pertaining to the case of the implementation of the invention and the tooth surfaces 26 of the second dog teeth 21 correspond to the fourth tooth surfaces pertaining to the case of the implementation of the invention.

[0037] The respective tooth surfaces 25, 26 are formed to be orthogonal to the direction of rotation in the example that is illustrated in FIG. 1. Point is, however, the piston 19 may not be separated from the second carrier 16 when the torque is transmitted with the respective tooth surfaces 25, 26 being in contact with each other. In other words, an axial load that is generated when the torque is transmitted with the respective tooth surfaces 25, 26 being in contact with each other, more specifically, the resultant force of the axial component of the frictional force generated in the tooth surfaces 25, 26, the spring force of the return spring 23, and the frictional force generated in the piston 19 and the fixed portion 5, may not act to separate the piston 19 from the second carrier 16. Accordingly, the respective tooth surfaces 25, 26 may be formed for the angle formed by top portions of the respective dog teeth 20, 21 and the tooth surfaces 25, 26 to be an obtuse angle as illustrated by the dashed line in FIG. 1 or may be formed for the angle formed by

top portions and the tooth surfaces 25, 26 to be an acute angle as illustrated by the one-dot chain line in FIG. 1. In the case of the formation in which the angle formed by the top portions and the tooth surfaces 25, 26 is an obtuse angle, the inclination angle may be determined so that the piston 19 is not separated from the second carrier 16 when the torque is transmitted with the respective tooth surfaces 25, 26 being in contact with each other as described above.

[0038] The negative torque that is transmitted to the second carrier 16 is reduced first when the transmission torque capacity of the first brake B1 begins to be increased during the setting of the forward first speed. When the transmission torque capacity of the first brake B1 is further increased thereafter, the torque that is transmitted to the second carrier 16 is reversed in direction to become the positive torque. In other words, an increase in the transmission torque capacity of the first brake B1 causes the direction of the torque that is transmitted to the second carrier 16 to be gradually reversed. When the direction of the torque that is transmitted to the second carrier 16 is reversed as described above, the meshing between the dog teeth 20, 21 is reversed. Accordingly, this automatic transmission is configured for the meshing between the dog teeth 20, 21 to be reversed and the thrust for separating the piston 19 from the second carrier 16 to be generated in accordance with the torque in the direction in which tooth surfaces 27, 28 are brought into contact with each other. Specifically, the tooth surfaces 27, 28 which are brought into contact with each other with the reversal of the meshing between the respective dog teeth 20, 21 are inclined so that the angle formed by the tooth surfaces 27, 28 and the top portions is an obtuse angle. The tooth surfaces 27, 28 are directed to be opposite to the respective tooth surfaces 25, 26 in the circumferential direction, and correspond to the first tooth surface and the third tooth surface pertaining to the case of the implementation of the invention.

[0039] The shapes of the respective tooth surfaces 27, 28 will be described in detail. The respective dog teeth 20, 21 are formed for the angle θ that is formed by the axial direction and the respective tooth surfaces 27, 28 to be equal to or larger than a predetermined value, that is, configured for a load to act on the piston 19 in the direction in

which the piston 19 is separated from the second carrier 16 in accordance with the torque which is applied to the respective tooth surfaces 27, 28 as a result of the contact between the respective tooth surfaces 27, 28. It is preferable that this inclination angle θ is set to an angle which satisfies the following expression.

$$5 \quad B - C - \mu_1 \times F > 0 \dots (1)$$

[0040] The B in the Expression (1) represents the load that acts on the piston 19 in accordance with the torque transmitted to the second carrier 16 so that the piston 19 is separated from the second carrier 16 when a load acts on the tooth surfaces 28. The B in the Expression (1) can be calculated based on a normal force A that is applied to the tooth surfaces 28 and the inclination angle θ . Specifically, the B in the Expression (1) can be calculated as follows. The F in the following equation represents the load in the direction of rotation acting on the piston 19.

$$B = A \times \sin \theta \dots (2)$$

$$A = F / \cos \theta \dots (3)$$

[0041] Since the frictional force is generated when the piston 19 is moved in the axial direction, the axial component of the frictional force acts on the piston 19. The C in the Expression (1) represents the axial component of the frictional force. Accordingly, the C can be obtained by the following equation. The μ_2 in the following equation represents the coefficient of friction in the contact surfaces of the respective dog teeth 20, 21.

$$C = \mu_2 \times A \times \cos \theta \dots (4)$$

[0042] In addition, the " $\mu_1 \times F$ " in the Expression (1) represents the frictional force that is caused by the piston 19 and the fixed portion 5, and the μ_1 represents the coefficient of friction in the contact surfaces of the piston 19 and the fixed portion 5.

[0043] Accordingly, the Expression (1) shows a condition in which the piston 19 can be moved in a case where the torque is applied to the respective tooth surfaces 27, 28 in a state where the pressing mechanism 22 does not press the piston 19. Because the return spring 23 always presses the piston 19, the spring force of the return spring 23 may be added to the left-hand side of the Expression (1).

[0044] When the second brake B2 has the above-described configuration, it is possible to allow the load to act on the piston 19 and release the second brake B2 by controlling the torque that is transmitted by the first brake B1. Specifically, when the transmission torque capacity of the first brake B1 is increased with the forward first speed set, the first brake B1 is in charge of a reaction force torque corresponding to the transmission torque capacity. Accordingly, the torque that is applied to the second brake B2 is gradually reduced. In other words, the first brake B1 and the second brake B2 are in charge of the reaction force torque. When the transmission torque capacity of the first brake B1 is further increased, the positive torque is transmitted to the second carrier 16 and the direction of the meshing of the second brake B2 is reversed. When the direction of the meshing of the second brake B2 is reversed as described above, the tooth surfaces 27, 28 are brought into contact with each other, and thus the second brake B2 is released when the piston 19 is not pressed to the second carrier 16 side by the pressing mechanism 22, more specifically, when oil supplied to the hydraulic actuator 24 is discharged.

[0045] In the automatic transmission that is illustrated in FIG. 6, the second brake B2 needs to be engaged when the reverse first speed or the reverse second speed is to be set as illustrated in FIGS. 7 and 8. In other words, the second carrier 16 needs to function as a reaction force element. However, the second sun gear 12 functions as an input element at the reverse first speed and the reverse second speed as illustrated in FIGS. 7 and 8, and thus a torque in a positive direction is transmitted to the second sun gear 12 during reverse traveling. Accordingly, during the reverse traveling, a torque is input so that the tooth surfaces 27, 28 are brought into contact with each other. When the torque is input as described above, an axial load is applied to the tooth surfaces 28 of the piston 19 so that the piston 19 is separated from the second carrier 16 as described above. Likewise, in the event of so-called engine brake in which a braking force is exerted by a pumping loss of the engine 3 or the like during the setting of the forward first speed, a torque in the positive direction is transmitted to the second sun gear 12, and an axial load is applied to the tooth surfaces 28 of the piston 19 so that the piston 19 is separated from the second carrier 16. Accordingly, this automatic transmission is configured for the piston 19 to be pressed to

the second carrier 16 side by the pressing mechanism 22 during the reverse traveling or the engine brake. More specifically, this automatic transmission is configured for the piston 19 not to be separated from the second carrier 16 with the hydraulic pressure supplied to the hydraulic actuator 24, that is, for an engagement state to be maintained.

5 **[0046]** Next, an example of control for the automatic transmission having the above-described configuration will be described with reference to the flowchart illustrated in FIG. 5. The flowchart illustrated in FIG. 5 is repeatedly executed at predetermined time intervals. According to the example illustrated in FIG. 5, it is determined first whether or not a request for the shifting from the forward first speed to the forward second speed is present (Step S1). Specifically, it is determined whether or not the currently set
10 transmission stage is the forward first speed and it is determined whether or not the request for the shifting from the forward first speed to the forward second speed is present in accordance with the vehicle speed and the accelerator opening or it is determined whether or not the request for the shifting is present in accordance with a shift lever position,
15 various switch operations, or the like. When the upshift is requested in a state where an accelerator pedal is depressed, it is preferable to improve the shift response. Accordingly, this control may be initiated in a case where the request for the shifting from the forward first speed to the forward second speed is present with the vehicle speed becoming equal to or greater than a predetermined vehicle speed in a state where the accelerator pedal is
20 depressed.

[0047] In a case where the request for the shifting from the forward first speed to the forward second speed is present and a positive determination is made in Step S1, the transmission torque capacity of the first brake B1 is increased (Step S2) so as to reduce the negative torque transmitted to the second carrier 16 or transmit the positive torque to the
25 second carrier 16. Specifically, the transmission torque capacity required for the first brake B1 is calculated first so that the torque applied to the second brake B2 becomes “zero”. This can be calculated based on the vehicle speed, the torque and the rotation speed of the input shaft 10, and the gear ratio. Then, the transmission torque capacity of the first brake B1 that is required for moving the piston 19 is calculated. Specifically, the

length of time required for the separation of the piston 19 is obtained and the transmission torque capacity of the first brake B1 is calculated so that the piston 19 can be separated within that length of time. The length of time required for the separation of the piston 19 can be determined based on the length of time required for a transition to an inertia phase
5 determined based on rates of change of the accelerator opening and the vehicle speed. As described above, the axial load acts on the piston 19 in accordance with the torque transmitted to the second carrier 16. Accordingly, the load that acts on the piston 19 can be obtained based on the length of time required for the release of the piston 19 determined as described above and the axial length of the meshing of the piston 19 and then the
10 transmission torque capacity of the first brake B1 can be calculated based on this load. Then, the transmission torque capacity required for the first brake B1 so that the torque acting on the second brake B2 becomes “zero” as described above and the transmission torque capacity of the first brake B1 calculated in accordance with the shifting speed are added and the transmission torque capacity of the first brake B1 is increased with the
15 added transmission torque capacity being a target value.

[0048] In addition, the hydraulic pressure of the hydraulic actuator 24 that controls the second brake B2 is reduced (Step S3). In other words, the thrust that acts on the piston 19 is reduced. Specifically, oil is discharged from a hydraulic pressure chamber of the hydraulic actuator 24. The determination of Step S3 is made in a case
20 where the hydraulic pressure is supplied to the hydraulic actuator 24 even in a state where the second brake B2 is engaged. In other words, the hydraulic pressure does not have to be supplied to the hydraulic actuator 24 in a case where the top portions and the respective tooth surfaces 25, 26 form an acute angle as described above because the piston 19 is not separated from the second carrier 16 when the second brake B2 is engaged. Accordingly,
25 Step S3 may not be executed in the case of a configuration in which no hydraulic pressure has to be supplied to the hydraulic actuator 24 when the second brake B2 is engaged. In Step S3, the hydraulic pressure may be controlled and reduced at the same time or, simply, the oil may be drained. In addition, Step S3 may be initiated prior to Step S2 or Step S2 and Step S3 may be initiated at the same time.

[0049] When the transmission torque capacity of the first brake B1 is increased as described above, the negative torque that is transmitted to the second carrier 16 is gradually reduced, and then the positive torque is transmitted to the second carrier 16. As a result, the respective tooth surfaces 27, 28 are brought into contact with each other. In this case, the hydraulic pressure of the hydraulic actuator 24 is reduced, and thus the piston 19 is separated from the second carrier 16 when the torque is applied with the respective tooth surfaces 27, 28 being in contact with each other. The first brake B1 is an engagement mechanism that is engaged for the setting of the forward second speed, and the first brake B1 is set to a transmission torque capacity exceeding the transmission torque capacity required for maintaining the forward first speed in the event of the shifting from the forward first speed to the forward second speed. Accordingly, the rotation speed of the second sun gear 12 changes to approach "zero" at the same time as the meshing between the respective dog teeth 20, 21 is cancelled. As a result, the rotation speed of the engine 3 is reduced. Then, the first brake B1 is engaged. Accordingly, in Step S3, it is determined whether or not the first brake B1 is engaged (Step S4). The determination of Step S4 can be made based on whether or not the engine rotation speed calculated based on the vehicle speed and the gear ratio at the forward second speed and the actual engine rotation speed are equal to each other.

[0050] A transition to the inertia phase is made when the rotation speed of the second sun gear 12 and the engine rotation speed begin to change at the same time as the second brake B2 is released as described above. During the transition to the inertia phase, the engine rotation speed is reduced as described above, and thus it can be determined whether or not the transition to the inertia phase is made based on the detection of the engine rotation speed. In a case where it is determined that the transition to the inertia phase is made, the transmission torque capacity of the first brake B1 and the output torque of the engine 3 may be switched for control for the inertia phase.

[0051] In a case where the first brake B1 has yet to be engaged and a negative determination is made in Step S4, Step S2 and Step S3 are repeatedly executed until the first brake B1 is engaged. In a case where the first brake B1 is engaged and a positive

determination is made in Step S4, this routine is temporarily terminated as it is.

[0052] In a case where the current transmission stage is not the forward first speed or in a case where the shifting to the forward second speed is not requested and a negative determination is made in Step S1 even though the current transmission stage is the forward first speed, a determination is made as to whether or not the operation state allows the engine brake to act in a state where the forward first speed is set (Step S5). The determination of Step S5 can be made based on, for example, whether or not known fuel cut control is executed or whether or not the forward first speed is selected through a shift lever operation even though the transmission stage determined from the accelerator opening and the vehicle speed is not the forward first speed.

[0053] In the case of an operation state allowing the engine brake to act and a positive determination in Step S5, the hydraulic pressure of the hydraulic actuator 24 is increased (Step S6) so that the piston 19 is not separated from the second carrier 16, and this routine is temporarily terminated. The target hydraulic pressure of the hydraulic actuator 24 for Step S6 can be calculated based on the inclination angle of the tooth surfaces 27, 28 and the transmitted torque.

[0054] In the case of an operation state not allowing the engine brake to act and a negative determination in Step S5, it is determined whether or not a reverse range is selected (Step S7). The determination of Step S7 can be made based on the detection of a shift lever position. In a case where the reverse range is selected and a positive determination is made in Step S7, the process moves to Step S6 and the hydraulic pressure of the hydraulic actuator 24 is increased. In a case where the reverse range is not selected and a negative determination is made in Step S7, this routine is temporarily terminated as it is.

[0055] When the inclined surface is formed in the piston 19 in the second brake B2 as described above, the second brake B2 can be released since the torque is applied to the second brake B2 so that the piston 19 is released when the transmission torque capacity of the first brake B1 setting the transmission stage following the shifting is increased. In other words, the second brake B2 can be released when the transmission torque capacity of

the first brake B1 is controlled during the shifting. Although it is preferable that the hydraulic pressure of the hydraulic actuator 24 is reduced in this case, the hydraulic pressure of the hydraulic actuator 24 may be simply reduced and the hydraulic pressure does not have to be controlled based on the detection of, for example, the extent to which the transmission torque capacity of the first brake B1 is increased. In other words, no coordination with the control of the transmission torque capacity of the first brake B1 is required. Accordingly, an increase in the complexity of the control of the shifting from the transmission stage set by the engagement of the second brake B2 to the transmission stage set by the release of the second brake B2 can be suppressed. In addition, the transition to the inertia phase can be made at the same time as the second brake B2 is released as described above without requiring any time for determining whether the torque applied to the second brake B2 is reduced and determining whether the second brake B2 is released. As a result, the shift response can be improved. In addition, the movement speed of the piston 19 can be improved since the second brake B2 is released by the piston 19 being pressed by the second carrier 16, and thus the length of time from the start of the release of the second brake B2 to the completion of the release can be shortened. Accordingly, the shift response can be further improved.

[0056] The piston 19 can be pressed to the second carrier 16 side by the pressing mechanism 22 while the engine brake acts and the reverse traveling is performed even if the tooth surfaces of the dog teeth on one side are formed to be inclined for the simplification of the shift control as described above. As a result, a state where the second brake B2 is engaged can be maintained in accordance with a required traveling state or the like. Accordingly, another device such as a friction clutch is unnecessary, and the automatic transmission can be compact in size. In many cases, the friction clutch is arranged for a friction plate to face the friction clutch and lubricant is continuously supplied in order to suppress a reduction in the durability of the friction plate. Accordingly, in a case where the friction clutch is disposed, a drag loss occurs due to the lubricant interposed between the friction plate and another friction plate. However, no friction clutch needs to be disposed in parallel to the second brake B2 in the automatic

transmission described above, and thus the occurrence of the drag loss can be suppressed. When the respective tooth surfaces 25, 26 are in contact with each other with the forward first speed set as described above, a load is unlikely to act to separate the piston 19 from the second carrier 16. Accordingly, the hydraulic pressure supplied to the hydraulic actuator 24 can be reduced when the forward first speed is set in comparison to a configuration having an engagement mechanism transmitting power by using a frictional force.

[0057] The first engagement mechanism according to the invention is not limited to being engaged when the transmission stage having the maximum transmission ratio (forward first speed) is set. For example, the first engagement mechanism according to the invention may be an engagement mechanism that is engaged when the forward second speed is set. In other words, the first brake B1 in FIG. 6 may be a toothrf brake in which inclined surfaces are formed in the dog teeth as illustrated in FIG. 1. In this case, the shifting can be performed by increasing the transmission torque capacity of the third clutch C3 to release the first brake B1 during the shifting from the forward second speed to the forward third speed.

[0058] In addition, the first engagement mechanism according to the invention is not limited to functioning to stop the rotating member. Instead, the first engagement mechanism according to the invention may be configured to function as a so-called clutch for connection between members rotating relative to each other. Specifically, a toothed clutch, dog clutch, in which the inclined surfaces are formed in the dog teeth as illustrated in FIG. 1 may take the place of the first clutch C1 in FIG. 6. In a case where the toothed clutch takes the place of the first clutch C1 as described above, the torque can be exerted to release the first clutch C1 by increasing the transmission torque capacity of the fourth clutch C4 during a transition from the forward fifth speed to the forward sixth speed.

[0059] In the example that has been described above, the upshift from the forward first speed to the forward second speed has been described as an example. However, the invention can also be applied to the case of shifting to a transmission stage higher than the forward second speed such as upshift from the forward first speed to the forward third

speed and upshift from the forward first speed to the forward fourth speed. In a case where the so-called “jump shift” is performed as described above, the transmission torque capacity of the third clutch C3 may be increased during the upshift to the forward third speed and the transmission torque capacity of the fourth clutch C4 may be increased during the upshift to the forward fourth speed.

[0060] In FIG. 1, a configuration in which the dog teeth are formed on the surfaces of the second carrier 16 and the piston 19 that face each other is illustrated as an example. However, as in known dog clutches, the fixed portion 5 and the rotating member may be configured to be engaged with each other by forming dog teeth on the outer circumferential surface of the rotating member and moving a sleeve which meshes with the dog teeth in the axial direction. In the case of this configuration in which the dog teeth are allowed to mesh by the sleeve as described above, the angle formed by the tooth surfaces of the dog teeth and an end surface of the sleeve or an end surface of the second carrier 16 may correspond to the inclination angle θ according to the example described above.

[0061] Next, another configuration example of the pressing mechanism according to the invention will be described. FIG. 2 is a schematic diagram for showing the example. The example illustrated in FIG. 2 is configured to press the piston 19 by using an electromagnetic force. This example is configured to have a coil 29 disposed in the fixed portion 5 and for the coil 29 to be energized so that a pressing force corresponding to the current value acts on the piston 19. In other words, the coil 29 and the piston 19 function as electromagnetic actuators and the electromagnetic actuators and the return spring 23 constitute the pressing mechanism. The rest of the configuration is similar to that of the example illustrated in FIG. 1. When the second brake B2 is released in this configuration, the energization of the coil 29 is stopped or the current that is opposite in direction to the case of the energization of the coil 29 is allowed to flow so that the second brake B2 is engaged and the piston 19 is separated from the second carrier 16. Accordingly, the second brake B2 can be released when the load acts on the tooth surfaces 27, 28.

[0062] In the examples illustrated in FIGS. 1 and 2, the dog teeth 20, 21 are formed in the piston 19. However, another configuration is also possible, as illustrated in FIG. 3, in which a shift fork 31 is provided with the piston 19 moving in the axial direction by receiving hydraulic pressure being connected to one end portion thereof and a meshing member 30 having the dog teeth 21 meshing with the dog teeth 20 being connected to the other end portion thereof. In other words, an axial thrust generated by a hydraulic actuator is transmitted to the meshing member 30 by the shift fork 31 in the configuration of the example illustrated in FIG. 3, and thus the hydraulic actuator, the shift fork 31, and the meshing member 30 constitute the pressing mechanism 22 in the configuration of the example illustrated in FIG. 3.

[0063] In addition, another configuration is possible in which the piston 19 is pressed by a so-called ball cam mechanism 32 as illustrated in FIG. 4. The configuration illustrated in FIG. 4 will be briefly described. In the ball cam mechanism 32 that is illustrated in FIG. 4, the back surface side of the piston 19 is formed at an angle to the direction of rotation, and the ball cam mechanism 32 is provided with a rotating member 33 where an inclined surface facing this inclined surface is formed. A ball 34 is pinched between the inclined surfaces. In addition, a protruding portion 35 that protrudes in the axial direction is formed on the side surface of the rotating member 33 on the side opposite to the side surface where the inclined surface is formed. A tip surface of the protruding portion 35 is arranged to be in contact with the fixed portion 5. In other words, the rotating member 33 is arranged to be incapable of moving in the axial direction. A hydraulic pressure chamber 36 is also formed so that a torque is generated in the rotating member 33 based on the hydraulic pressure which acts on the protruding portion 35.

[0064] In the ball cam mechanism 32 that has the above-described configuration, the protruding portion 35 is pressed in the circumferential direction and the torque is generated in the rotating member 33 when hydraulic pressure is supplied to the hydraulic pressure chamber 36. This torque is transmitted to the piston 19 via the ball 34 that is in contact with the inclined surface, and the piston 19 is pressed in the axial direction in accordance with the torque transmitted to the piston 19 and the inclination angle of the

inclined surface formed in the piston 19. When the hydraulic pressure of the hydraulic pressure chamber 36 is reduced and a load acts on the tooth surfaces 27, 28 as described above, the piston 19 is pressed to the rotating member 33 side. When the piston 19 is pressed as described above, the ball 34 and the rotating member 33 are pressed in the axial direction. However, since the rotating member 33 is arranged to be incapable of moving in the axial direction as described above, the ball 34 rolls on the inclined surface to rotate the rotating member 33 and the rotating member 33 rotates. As a result, the piston 19 is separated from the second carrier 16. In other words, the rotating member 33 functions as a hydraulic actuator. Even in a case where this configuration is adopted, selective switching is allowed between maintaining a state where the second brake B2 is engaged and releasing the second brake B2, based on the control of the hydraulic pressure supplied to the hydraulic pressure chamber 36, when the torque acts with the tooth surfaces 27, 28 being in contact with each other.

[0065] Next, another example of the automatic transmission that can be an object of the invention will be briefly described with reference to the skeleton diagram illustrated in FIG. 9. Like reference numerals will be used to refer to like parts of the configuration of the automatic transmission illustrated in FIG. 6, and description thereof will be omitted. The automatic transmission illustrated in FIG. 9 is configured to allow the setting of transmission stages from the forward first speed to the forward sixth speed and the reverse first speed. Specifically, a single pinion-type planetary gear mechanism (hereinafter, referred to as a third planetary gear mechanism 37) and a Ravigneaux-type planetary gear mechanism (hereinafter, referred to as a fourth planetary gear mechanism 38) constitute the automatic transmission illustrated in FIG. 9.

[0066] A fourth sun gear 39 that is connected to the engine 3 via a torque converter (not illustrated), a third ring gear 40 that is concentrically arranged with the fourth sun gear 39, a pinion gear 41 that meshes with the fourth sun gear 39 and the third ring gear 40, and a third carrier 42 that holds the pinion gear 41 to be capable of rotation and revolution constitute the third planetary gear mechanism 37 illustrated in FIG. 9.

[0067] A fifth sun gear 43 that is concentrically arranged with the input shaft 10

and is connected to the third carrier 42, a sixth sun gear 44 that is concentrically arranged with the input shaft 10 and is arranged to be adjacent to the fifth sun gear 43, a third inner pinion gear 45 that meshes with the fifth sun gear 43, a third outer pinion gear 46 that meshes with the sixth sun gear 44 and the third inner pinion gear 45, a fourth ring gear 47
5 that meshes with the third outer pinion gear 46, and a fourth carrier 49 that holds the third inner pinion gear 45 and the third outer pinion gear 46 to be capable of rotation and revolution and is connected to an output gear 48 constitute the fourth planetary gear mechanism 38 illustrated in FIG. 9. In other words, the fourth planetary gear mechanism 38 is configured as a differential mechanism that has the four rotating elements of the fifth
10 sun gear 43, the sixth sun gear 44, the fourth carrier 49, and the fourth ring gear 47.

[0068] A fifth clutch C5 is disposed to connect the input shaft 10 or the fourth sun gear 39 and the sixth sun gear 44 to each other, and a sixth clutch C6 is disposed to connect the input shaft 10 or the fourth sun gear 39 and the fourth ring gear 47 to each other. In addition, a third brake B3 is disposed to stop the third carrier 42, a fourth brake B4 is
15 disposed to stop the fourth ring gear 47, and a fifth brake B5 is disposed to stop the third ring gear 40.

[0069] In the example illustrated in FIG. 9, the fifth clutch C5, the sixth clutch C6, the third brake B3, and the fifth brake B5 are configured to transmit a torque by using a frictional force and the fourth brake B4 is configured to transmit a torque by meshing.

20 [0070] In this automatic transmission, the forward first speed is set when the fifth clutch C5 and the fourth brake B4 are engaged, the forward second speed is set when the fifth clutch C5 and the third brake B3 are engaged, the forward third speed is set when the fifth clutch C5 and the fifth brake B5 are engaged, the forward fourth speed is set when the fifth clutch C5 and the sixth clutch C6 are engaged, the forward fifth speed is set when the
25 sixth clutch C6 and the fifth brake B5 are engaged, and the forward sixth speed is set when the sixth clutch C6 and the third brake B3 are engaged as illustrated in FIG. 10. The reverse first speed is set when the fourth brake B4 and the fifth brake B5 are engaged.

[0071] The operation state of each rotating element of the automatic transmission that has the configuration illustrated in FIG. 10 is illustrated in FIG. 11. At the forward

first speed, the sixth sun gear 44 functions as an input element of the fourth planetary gear mechanism 38 since the fifth clutch C5 is engaged and the fourth ring gear 47 functions as a reaction force element and the fourth carrier 49 functions as an output element since the fourth brake B4 is engaged as illustrated in FIGS. 10 and 11. Accordingly, the negative torque is applied to the fourth brake B4 in a case where the forward first speed is set and a driving force is transmitted to the output gear 48.

[0072] At the forward second speed, the sixth sun gear 44 functions as an input element of the fourth planetary gear mechanism 38 since the fifth clutch C5 is engaged and the fifth sun gear 43 functions as a reaction force element of the fourth planetary gear mechanism 38 and the fourth carrier 49 functions as an output element since the third brake B3 is engaged and the fifth sun gear 43 is stopped via the third carrier 42.

[0073] Accordingly, the fourth brake B4 is released and the third brake B3 is engaged during the shifting from the forward first speed to the forward second speed. When the transmission torque capacity of the third brake B3 is increased in this case, the negative torque that is transmitted to the fourth ring gear 47 is gradually reduced as is illustrated in FIG. 6, and then the positive torque begins to be transmitted to the fourth ring gear 47. In other words, the torque that is applied to the fourth brake B4 is reversed. Accordingly, effects similar to those of the example illustrated in FIG. 6 can be achieved when the fourth brake B4 is configured to have the dog teeth illustrated in FIG. 1.

[0074] In the automatic transmission illustrated in FIG. 9, the positive torque is applied to the fourth brake B4, which is a toothed brake, as in the automatic transmission illustrated in FIG. 6 not only when the engine brake acts in a state where the forward first speed is set but also when the reverse first speed is set and the driving force is output. The toothed brake has a structure of a dog clutch. In other words, the torque is applied in the direction opposite to the direction during forward traveling. Accordingly, effects similar to those of the example described above can be achieved when the pressing mechanism 22 is disposed in the fourth brake B4 as in the example described above.

[0075] The automatic transmission according to the invention is not limited to setting the transmission stage by engaging the rotating elements of the planetary gear

mechanisms with each other as illustrated in FIG. 6 or fixing any one of the rotating elements. Instead, the automatic transmission according to the invention may be an automatic transmission having a configuration in which a plurality of gears are connected to an input shaft to be capable of relative rotation, any one of the gears and the input shaft
5 are engaged with each other by a dog clutch for the setting of a first transmission stage, and the other gear and the input shaft are engaged with each other by a friction clutch for shifting to a second transmission stage which has a lower transmission ratio than a predetermined transmission stage.

CLAIMS:

1. An automatic transmission comprising:

a first engagement mechanism including a first member, a second member, and a pressing mechanism, the first member including first dog teeth, the second member including second dog teeth meshing with the first dog teeth when the second member is moved in an axial direction, the first dog teeth including first tooth surfaces directed to one side in a circumferential direction and second tooth surfaces directed to the other side in the circumferential direction, the second dog teeth including third tooth surfaces facing the first tooth surfaces and fourth tooth surfaces facing the second tooth surfaces, and the pressing mechanism being configured to press the second member to the first member side so as to maintain a state where the first tooth surfaces and the third tooth surfaces are in contact with each other; and

an electronic control unit configured to control the first engagement mechanism to be engaged when a first transmission stage is selected among a plurality of transmission stages of the automatic transmission, the electronic control unit being configured to control the first engagement mechanism to be released when a second transmission stage is selected among the plurality of transmission stages of the automatic transmission,

wherein the first tooth surfaces and the third tooth surfaces include inclined surfaces such that a thrust for separating the first member and the second member from each other in the axial direction is generated in accordance with a torque in a direction in which the first tooth surfaces and the third tooth surfaces are brought into contact with each other during shifting from the first transmission stage to the second transmission stage.

2. The automatic transmission according to claim 1,

wherein the first transmission stage is any one of a plurality of forward transmission stages of the automatic transmission, the electronic control unit is configured to control the first engagement mechanism to be engaged when the first transmission stage or a reverse transmission stage is selected, the first engagement mechanism is configured to transmit a

torque by the second tooth surfaces and the fourth tooth surfaces being in contact with each other when the first transmission stage is selected, and the first engagement mechanism is configured to transmit a torque by the first tooth surfaces and the third tooth surfaces being in contact with each other when the reverse transmission stage is selected.

3. The automatic transmission according to claim 2,

wherein the electronic control unit is configured to control the pressing mechanism such that the second member is pressed to the first member side when engine brake acts or when the reverse transmission stage is selected while the first transmission stage is selected.

4. The automatic transmission according to any one of claims 1 to 3,

wherein the pressing mechanism includes an elastic body and an actuator, the elastic body is configured to press the second member to one side in the axial direction, and the actuator is configured to generate a load against a load with which the second member is pressed by the elastic body.

5. The automatic transmission according to claim 4,

wherein the actuator is configured to generate a load corresponding to a supplied hydraulic pressure.

6. The automatic transmission according to claim 4,

wherein the actuator is configured to generate a load corresponding to an amount of a current with which the actuator is energized.

7. The automatic transmission according to any one of claims 4 to 6,

wherein the elastic body is configured to exert an elastic force in a direction in which the second member is separated from the first member, the second tooth surfaces and the fourth tooth surfaces including inclined surfaces inclined with respect to directions of

rotation of the first member and the second member such that the second member is not separated from the first member by the elastic force of the elastic body when the second tooth surfaces and the fourth tooth surfaces are in contact with each other and when the actuator generates no load.

8. The automatic transmission according to any one of claims 1 to 7, further comprising:

a second engagement mechanism configured to connect a third member and a fourth member disposed to be capable of relative rotation to each other so as to transmit a torque between the third member and the fourth member,

wherein the electronic control unit is configured to control the first engagement mechanism to be engaged and control the second engagement mechanism to be released when the first transmission stage is selected, and the electronic control unit is configured to control the first engagement mechanism to be released and control the second engagement mechanism to be engaged when the second transmission stage is selected.

9. The automatic transmission according to claim 8,

wherein the second engagement mechanism is configured to change a capacity of the torque transmitted between the third member and the fourth member, and the first engagement mechanism is configured for the direction of a torque acting on the first member or the second member to be gradually reversed in response to an increase in the capacity of the torque.

10. The automatic transmission according to claims 1 to 9,

wherein the first engagement mechanism is a toothed brake.

11. The automatic transmission according to any one of claims 1 to 9,

wherein the first member and the second member are configured to rotate relative to each other, the first engagement mechanism being a clutch mechanism connecting the first

member and the second member to each other for integral rotation when the respective dog teeth mesh with each other.

12. The automatic transmission according to any one of claims 1 to 11, further comprising:

a third engagement mechanism,

wherein the electronic control unit is configured to control the third engagement mechanism to be engaged when the first transmission stage is selected or when the second transmission stage is selected.

13. The automatic transmission according to any one of claims 1 to 12, further comprising:

a first planetary gear mechanism including three rotating elements; and

a second planetary gear mechanism including three rotating elements,

wherein the first engagement mechanism is configured to connect any of the rotating elements of the first planetary gear mechanism or any of the rotating elements of the second planetary gear mechanism to each other or fix any of the rotating elements.

14. The automatic transmission according to claim 8 or 9, further comprising:

a first planetary gear mechanism including three rotating elements; and

a second planetary gear mechanism including three rotating elements,

wherein the second engagement mechanism is configured to connect any of the rotating elements of the first planetary gear mechanism or any of the rotating elements of the second planetary gear mechanism to each other or fix any of the rotating elements.

15. The automatic transmission according to claim 12, further comprising:

a first planetary gear mechanism including three rotating elements; and

a second planetary gear mechanism including three rotating elements,

wherein the third engagement mechanism is configured to connect any of the rotating

elements of the first planetary gear mechanism or any of the rotating elements of the second planetary gear mechanism to each other or fix any of the rotating elements.

FIG. 1

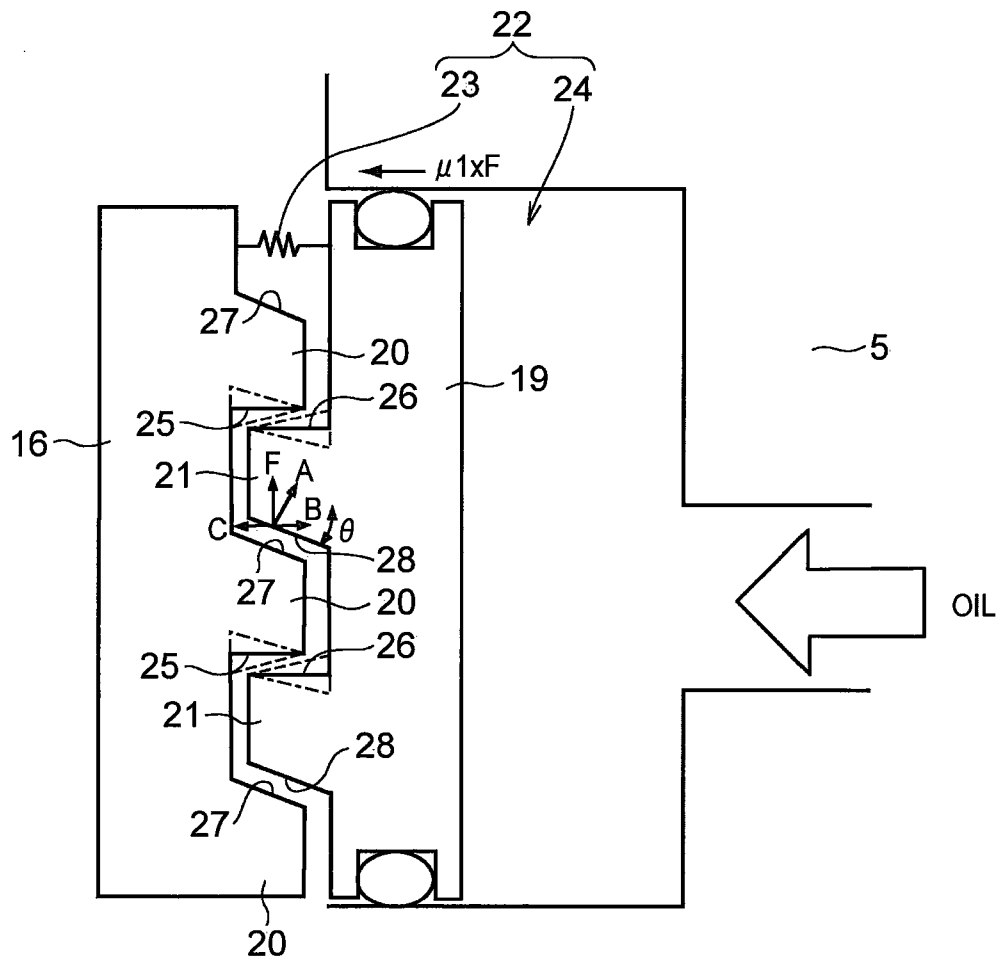


FIG. 2

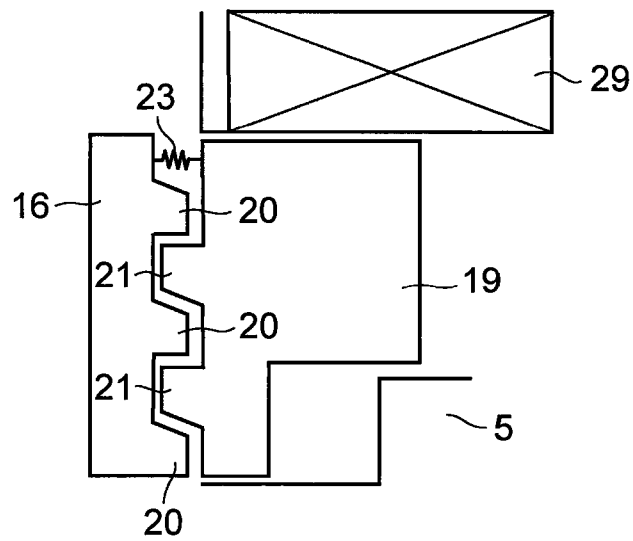


FIG. 3

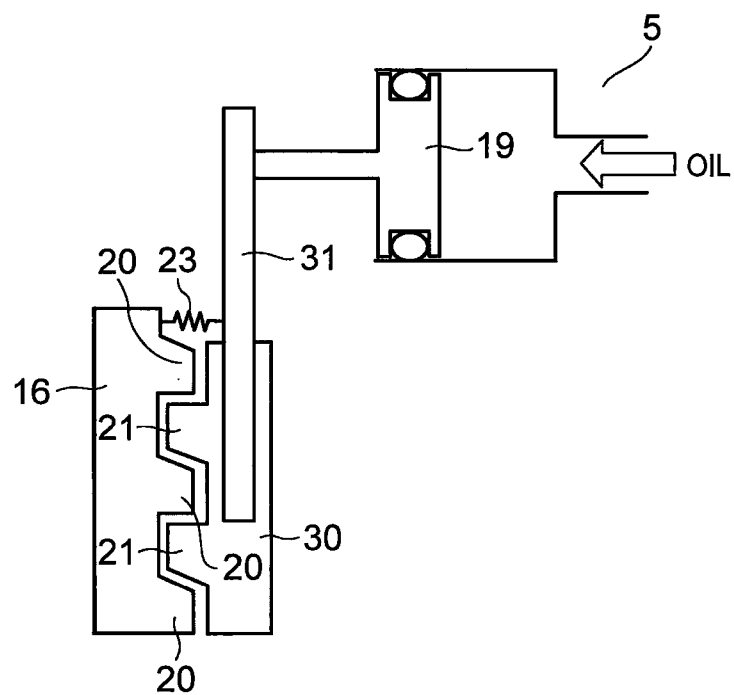


FIG. 4

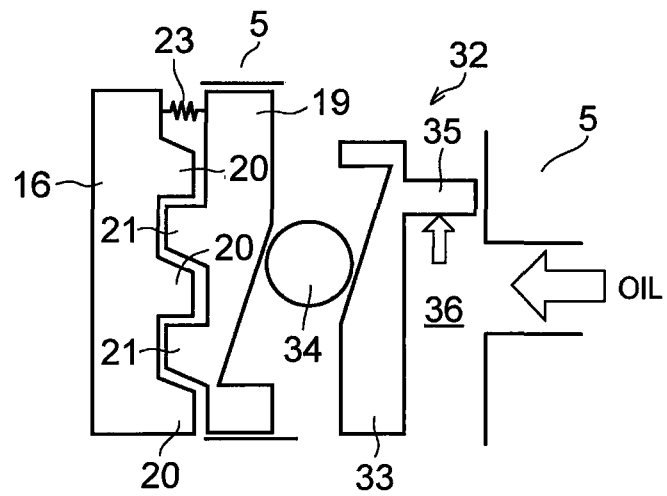


FIG. 5

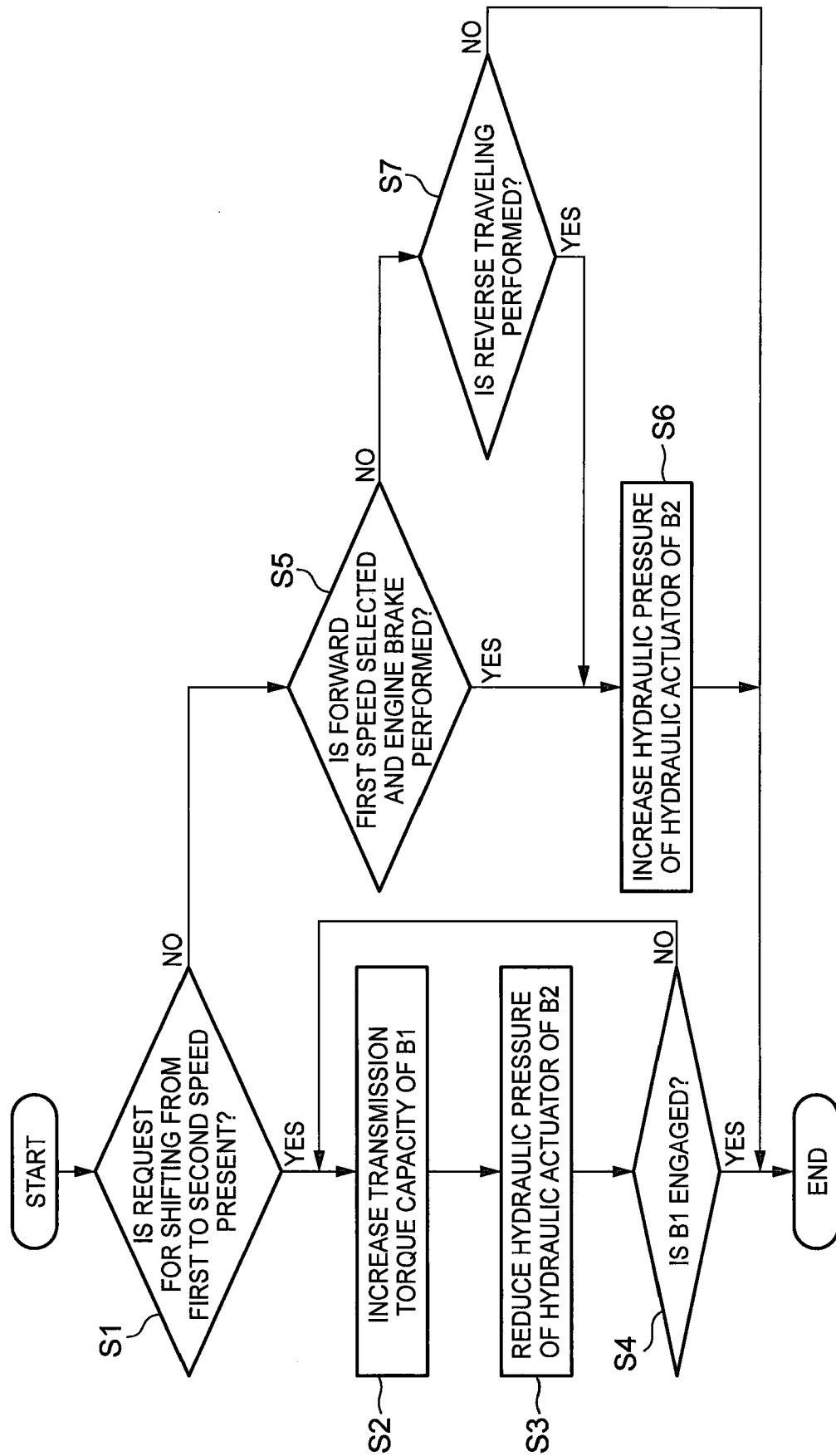


FIG. 6

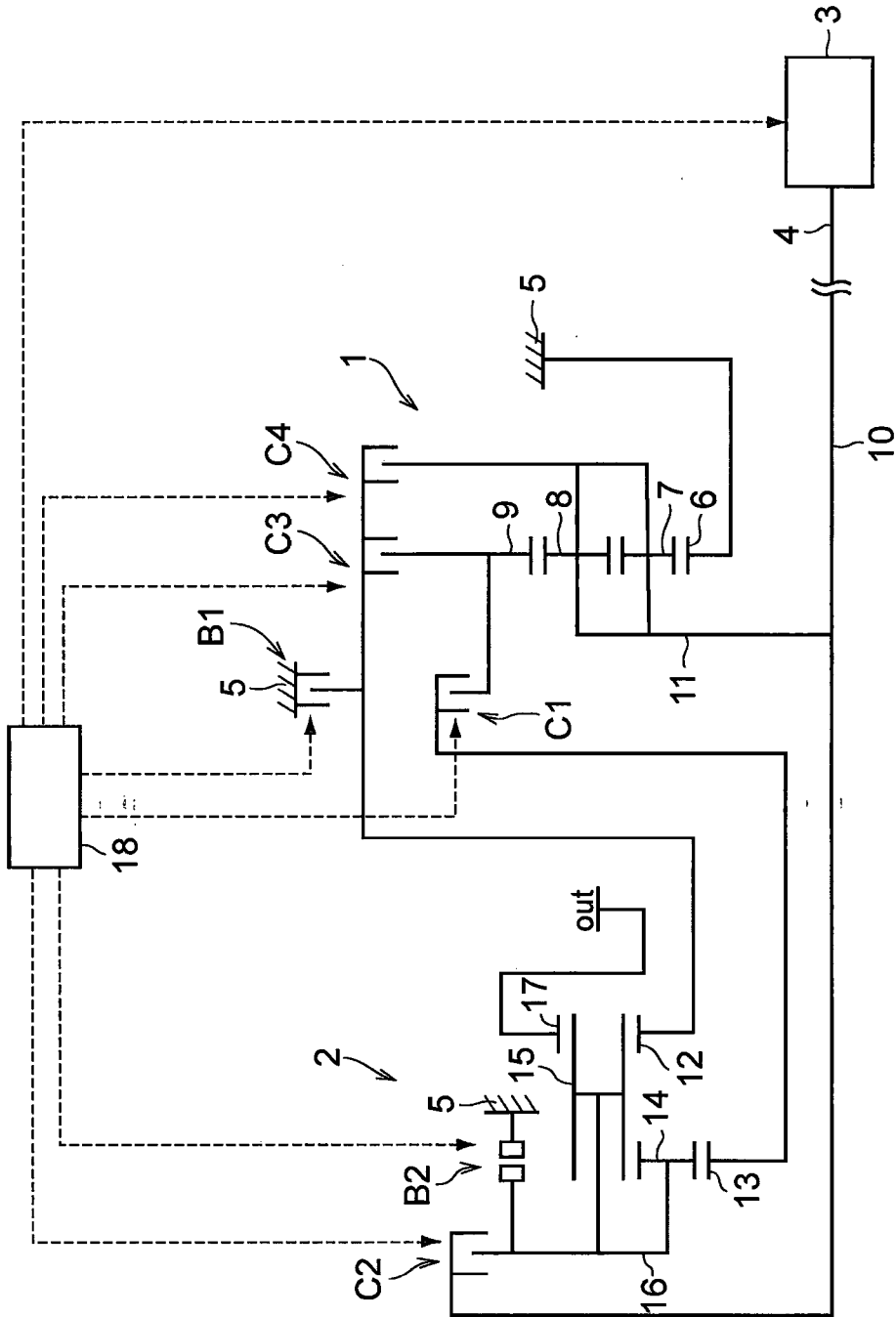


FIG. 7

TRANSMISSION STAGE	C1	C2	C3	C4	B1	B2
1st	O	-	-	-	-	O
2nd	O	-	-	-	O	-
3rd	O	-	O	-	-	-
4th	O	-	-	O	-	-
5th	O	O	-	-	-	-
6th	-	O	-	O	-	-
7th	-	O	O	-	-	-
8th	-	O	-	-	O	-
Revs1	-	-	O	-	-	O
Revs2	-	-	-	O	-	O

O:ENGAGED
-:RELEASED

FIG. 8

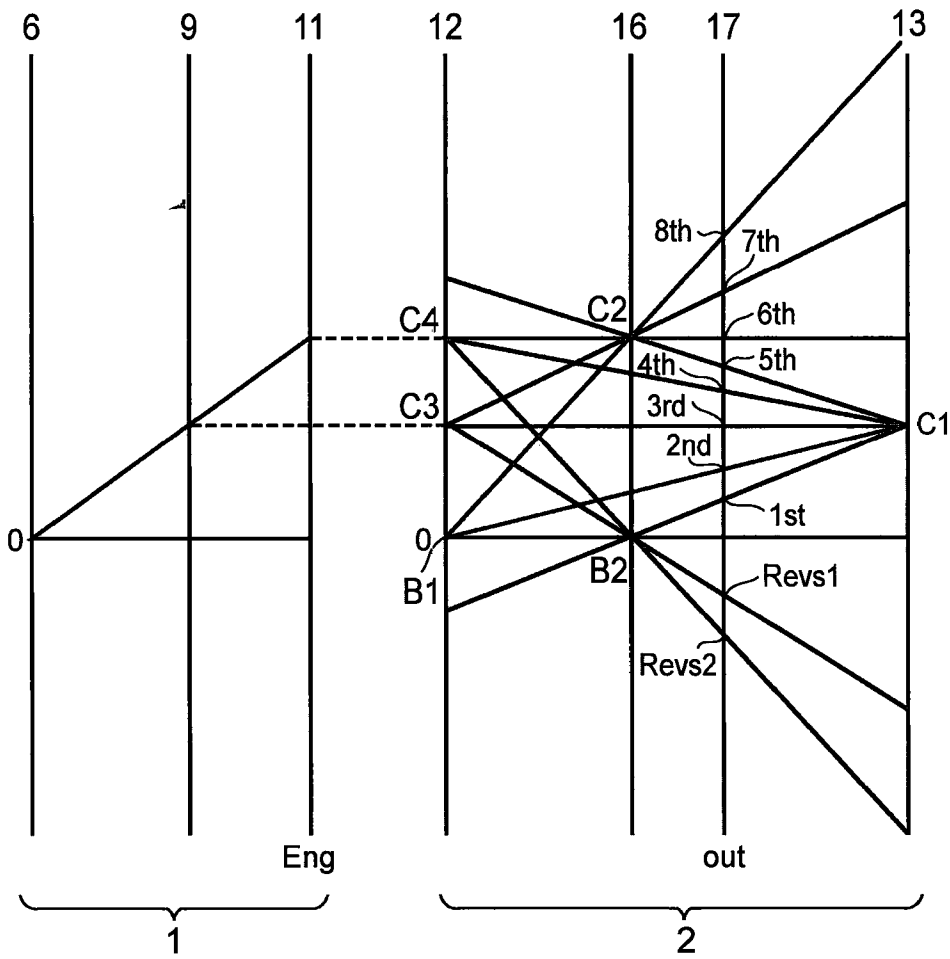


FIG. 9

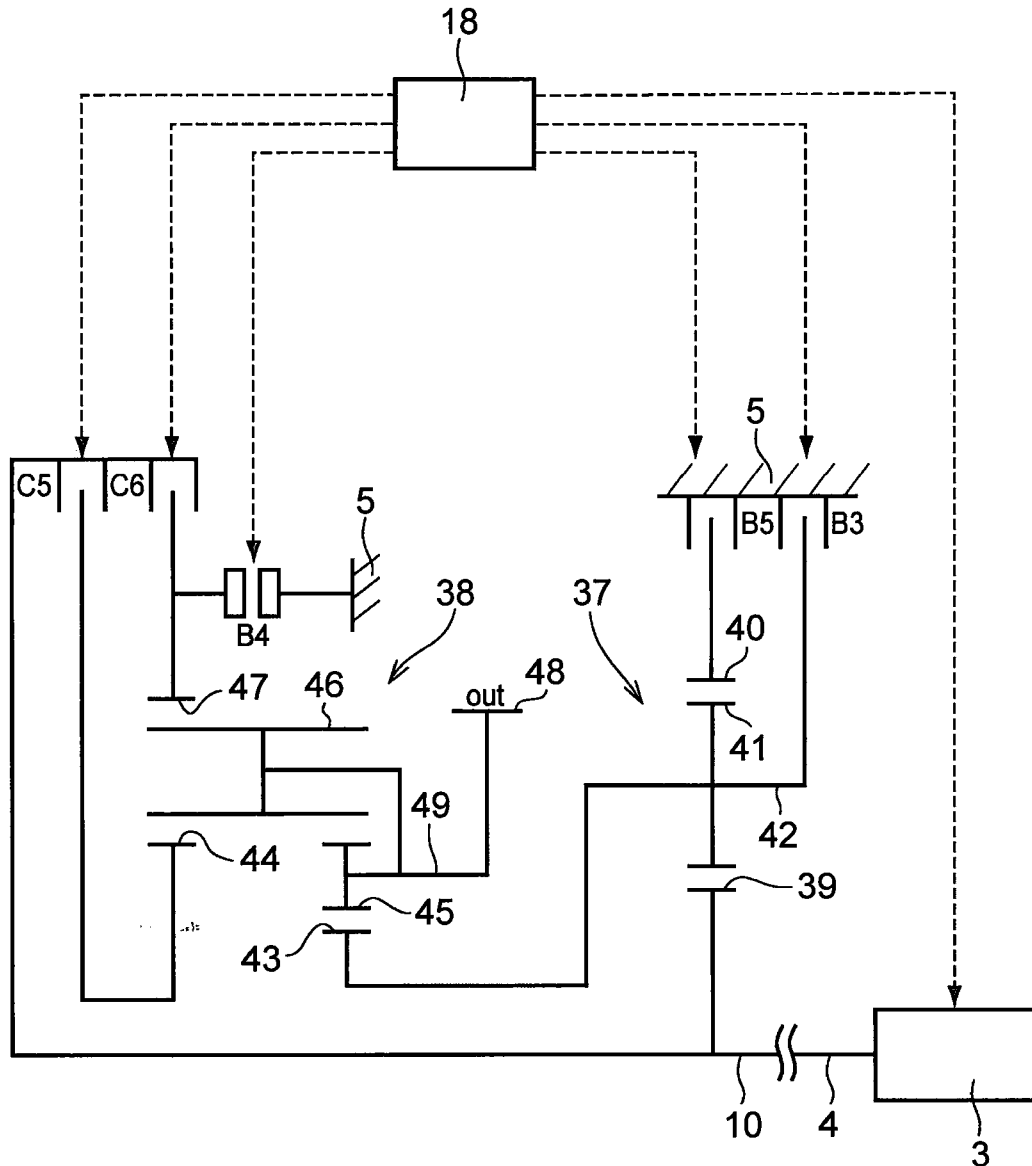


FIG. 10

TRANSMISSION STAGE	C5	C6	B3	B4	B5
1st	○	-	-	○	-
2nd	○	-	○	-	-
3rd	○	-	-	-	○
4th	○	○	-	-	-
5th	-	○	-	-	○
6th	-	○	○	-	-
Revs1	-	-	-	○	○

○:ENGAGED
- :RELEASED

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/001165

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H61/04 F16H61/686
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16H F16D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/024652 A1 (ISHII DAISUKE [JP] ET AL) 2 February 2012 (2012-02-02) the whole document -----	1,4-7, 10,11
A	US 5 699 871 A (HARA TOMOYUKI [JP] ET AL) 23 December 1997 (1997-12-23) figures 29-34 -----	1-15
A	DE 10 2011 108024 A1 (DAIMLER AG [DE]) 15 March 2012 (2012-03-15) the whole document -----	1-15
A	WO 2013/076827 A1 (TOYOTA JIDOSHA KK) 30 May 2013 (2013-05-30) cited in the application the whole document & EP 2 784 349 A1 (TOYOTA MOTOR CO LTD [JP]) 1 October 2014 (2014-10-01) the whole document -----	1-15

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Further documents are listed in the continuation of Box C.

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See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 September 2015

Date of mailing of the international search report

06/10/2015

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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		US 2014298790 A1	09-10-2014
		WO 2013076827 A1	30-05-2013
