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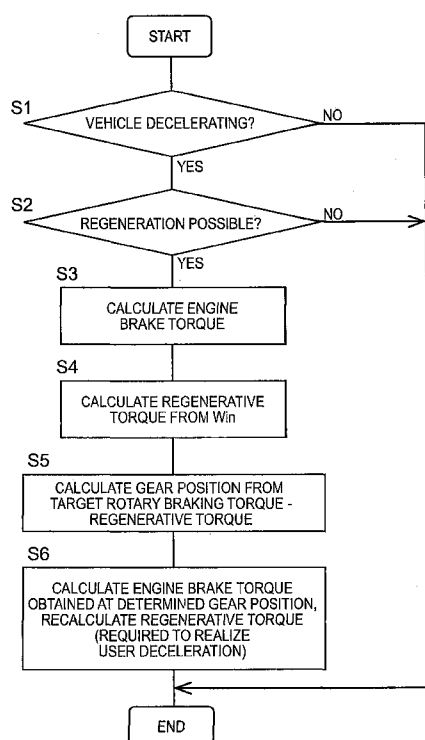
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[Continued on next page]

(54) Title: CONTROL APPARATUS FOR HYBRID VEHICLE

FIG. 3



(57) Abstract: A control apparatus for a hybrid vehicle includes: a motor (MG) coupled to a drive wheel (12); an engine (12) coupled to a drive wheel (22) via a transmission (16); a energy storage device that exchanges power with the motor; and a controller (40) configured to cause the motor to perform a regeneration operation when the vehicle decelerates. The controlled is configured to set the gear ratio of the transmission depending on the charge state of the energy storage device, in particular to set a high gear when regeneration capacity is high. Engine is drag is minimized and energy recuperation is increased.



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CONTROL APPARATUS FOR HYBRID VEHICLE

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to a control apparatus for a hybrid vehicle including an engine and a motor, wherein the engine is coupled to a drive wheel via a transmission, a energy storage device performs power exchange with the motor, and a regeneration operation is performed by the motor when the vehicle decelerates, and more particularly to
10 a technique for securing a degree of deceleration required by a driver during vehicle deceleration while improving fuel efficiency.

2. Description of Related Art

[0002] In a conventional hybrid vehicle including an engine and a motor, the
15 engine is coupled to a drive wheel via a transmission, a energy storage device performs power exchange with the motor, and a regeneration operation is performed by the motor when the vehicle decelerates. An example of this type of hybrid vehicle is a so-called single motor type hybrid vehicle such as that disclosed in Japanese Patent Application Publication No. 09-009415 (JP 09-009415 A).

20 [0003] When the single motor type hybrid vehicle of JP 09-009415 A decelerates, a shift point of the transmission during regenerative braking by the motor is shifted to a lower vehicle speed side than normal. In other words, an operation region in which a gear position on a high gear side of the transmission is selected is enlarged. Hence, a gear position on the high gear side of the transmission is selected during braking, leading to a
25 reduction in engine rotation and a reduction in engine braking, and therefore a braking force generated during regeneration by the motor can be increased correspondingly. As a result, a regeneration efficiency of the motor can be improved, enabling an improvement in fuel efficiency.

SUMMARY OF THE INVENTION

[0004] Braking force is obtained in the hybrid vehicle during deceleration from the braking force generated during regeneration by the motor and the engine brake. When, at this time, regeneration by the motor is limited due to a restriction on an input
5 current input into the energy storage device or the like, for example, the braking force generated during regeneration by the motor may decrease. When, at this time, the braking force generated by the engine brake is reduced during regenerative braking in accordance with the gear position selection, the braking force of the hybrid vehicle, combining the braking force generated during regeneration by the motor and the braking
10 force generated by the engine brake, may decrease.

[0005] The invention provides a control apparatus for a hybrid vehicle with which a reduction in a braking force is suppressed and a fuel efficiency is improved when the hybrid vehicle decelerates.

[0006] A control apparatus for a hybrid vehicle according to an aspect of the
15 invention includes: a motor coupled to a drive wheel; an engine coupled to a drive wheel via a transmission; a energy storage device that exchanges power with the motor; and a controller configured to perform a regeneration operation by the motor when the vehicle decelerates, the controller being configured to select, as a gear position of the transmission, a higher gear position as a regeneration capacity permitted in the motor increases while the
20 vehicle decelerates.

[0007] In the control apparatus for a hybrid vehicle thus configured, the vehicle is decelerated by selecting, as the gear position of the transmission, a higher gear position as the allowable regeneration capacity of the motor increases. Since the higher gear position of the transmission is selected, a braking force generated by an engine brake decreases, and
25 therefore an amount of regeneration performed by the motor can be increased correspondingly, leading to an improvement in fuel efficiency. Further, when the allowable regeneration capacity of the motor is small, a lower gear position of the transmission can be selected, and therefore the braking force generated by the engine brake can be increased in accordance with the reduction in the braking force generated during

regeneration by the motor, whereby a sufficient braking force can be secured in the vehicle. As a result, a reduction in braking force when the hybrid vehicle decelerates can be suppressed, and an improvement in fuel efficiency can be achieved.

[0008] In the control apparatus for a hybrid vehicle according to this aspect of the invention, the regeneration capacity permitted in the motor may set a higher value as a state of charge of the energy storage device decreases while the vehicle decelerates. In this case, the amount of regeneration performed by the motor can be increased as the state of charge of the energy storage device decreases, while the braking force generated by the engine brake can be increased as the state of charge of the energy storage device increases. As a result, a reduction in braking force when the hybrid vehicle decelerates can be suppressed, and an improvement in fuel efficiency can be achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] 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 conceptual diagram showing a configuration of a drive system and a control system pertaining to a hybrid vehicle to which the invention is favorably applied;

FIG. 2 is a functional block diagram illustrating main parts of control functions provided in an electronic control apparatus of the hybrid vehicle shown in FIG. 1; and

FIG. 3 is a flowchart illustrating an example of a control operation executed by the electronic control apparatus shown in FIG. 1 to control regeneration by a motor and a speed change by an automatic transmission during vehicle deceleration.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] An embodiment of the invention will be described in detail below on the basis of the drawings.

[0011] FIG. 1 is a conceptual diagram showing a configuration of a drive system and a control system pertaining to a hybrid vehicle driving apparatus 10 (to be referred to

hereafter simply as the driving apparatus 10) according to this embodiment of the invention. As shown in FIG. 1, the driving apparatus 10 includes an engine 12 and a motor MG that respectively function as drive sources, and is configured such that driving force generated by the engine 12 and the motor MG is transmitted to a left-right pair of drive wheels 22 via a torque converter 14, an automatic transmission (a transmission) 16, a differential gear apparatus 18, and a left-right pair of axles 20. In other words, the driving apparatus 10 includes the engine 12 and the motor MG, and the engine 12 is coupled to the drive wheels 22 via the automatic transmission 16 to be capable of transmitting power thereto. Further, the motor MG, the torque converter 14, and the automatic transmission 16 are all housed in a transmission case 24 (to be referred to hereafter as the case 24).

[0012] The automatic transmission 16, which is provided on a power transmission path between the motor MG and the drive wheels 22, is a planetary gear type speed change mechanism that includes a plurality of hydraulic frictional engagement devices and establishes a plurality of predetermined shift positions selectively in accordance with engagement and disengagement combinations of the frictional engagement devices. Note that respective engagement conditions of the plurality of hydraulic frictional engagement devices are controlled between engagement (full engagement), slip engagement, and disengagement (full disengagement) in accordance with oil pressure supplied from an oil pressure control circuit 26. Further, a mechanical oil pressure pump 28 is coupled to a pump impeller 14p of the torque converter 14 so that as the pump impeller 14p rotates, oil pressure generated by the oil pressure pump 28 is supplied to the oil pressure control circuit 26 as source pressure.

[0013] The motor MG is a motor/generator that includes a rotor 30 supported by the case 24 to be capable of rotating axially and a stator 32 fixed integrally to the case 24 on an outer peripheral side of the rotor 30, and functions as both a motor that generates driving force and a generator that generates counterforce. The motor MG is connected to a energy storage device 36 such as a battery or a capacitor via an inverter 34 to be capable of exchanging power therewith, and electric energy generated by the motor MG during regeneration, for example, is charged to the energy storage device 36 via the inverter 34.

[0014] A clutch K0 is provided on a power transmission path between the engine 12 and the motor MG to control power transmission on the power transmission path in accordance with an engagement condition thereof. In other words, a crankshaft 38 serving as an output member of the engine 12 is coupled selectively to the rotor 30 of the motor MG via the clutch K0.

[0015] The driving apparatus 10 includes a control system such as that shown in FIG. 1. An electronic control apparatus 40 shown in FIG. 1 is constituted by a so-called microcomputer having a central processing unit (CPU), a random access memory (RAM), a read only memory (ROM), and an input/output interface, wherein the CPU executes various types of control, such as regeneration control of the motor MG and speed change control of the automatic transmission 16, for example, by performing signal processing in accordance with a program stored in advance in the ROM while using a temporary storage function of the RAM. In an embodiment of the invention, the electronic control apparatus 40 corresponds to a control apparatus for a hybrid vehicle (the driving apparatus 10).

[0016] As shown in FIG. 1, various input signals detected by respective sensors provided in the driving apparatus 10 are supplied to the electronic control apparatus 40. For example, a signal representing an accelerator depression amount Acc (%) detected by an accelerator depression amount sensor 42 in accordance with a depression amount of an accelerator pedal, not shown in the drawing, a signal representing a vehicle speed V (km/h) detected by a vehicle speed sensor 44, a signal representing a state of charge SOC (%) of the energy storage device 36, detected by a SOC sensor 46, and so on are input into the electronic control apparatus 40.

[0017] Further, various output signals are supplied to various devices provided in the driving apparatus 10 from the electronic control apparatus 40. For example, a signal supplied to the inverter 34 to control regeneration by the motor MG, a signal supplied to a plurality of solenoid control valves in the oil pressure control circuit 26 to control a speed change by the automatic transmission 16, and so on are supplied to respective parts from the electronic control apparatus 40.

[0018] FIG. 2 is a functional block diagram illustrating main parts of control

functions provided in the electronic control apparatus 40. A deceleration determination unit 50 shown in FIG. 2 determines whether or not the vehicle is decelerating from the accelerator depression amount Acc (%) detected by the accelerator depression amount sensor 42, for example. For example, the deceleration determination unit 50 determines that the vehicle is decelerating when a depression operation of an accelerator pedal, not shown in the drawings, is stopped, or in other words when an accelerator OFF operation is performed.

[0019] A regeneration possibility determination unit 52 determines whether or not regeneration by the motor MG is possible. For example, the regeneration possibility determination unit 52 determines that regeneration by the motor MG is impossible when the SOC (%) of the energy storage device 36, detected by the SOC sensor 46, equals or exceeds a predetermined value, more specifically an upper limit value SOC_H at which the energy storage device 36 cannot be charged further, or when a temperature of the motor MG or the energy storage device 36 reaches or exceeds a predetermined temperature, or in other words when the motor MG or the energy storage device 36 enters an overheated condition.

[0020] When the deceleration determination unit 50 determines that the vehicle is decelerating and the regeneration possibility determination unit 52 determines that regeneration by the motor MG is possible, a target deceleration control unit 54 calculates a target rotary braking torque T_G at which a target deceleration G required by the driver during vehicle deceleration is realized, and controls a regenerative torque T_{MG} of the motor MG and an engine brake torque T_E to realize the calculated target rotary braking torque T_G . Note that the target deceleration control unit 54 calculates the target rotary braking torque T_G for use during vehicle deceleration on the basis of the actual vehicle speed V detected by the vehicle speed sensor 44 from a stored relationship between the vehicle speed V and the target rotary braking torque T_G , which is determined in advance through experiment such that the target deceleration G , or in other words the target rotary braking torque T_G , increases as the vehicle speed V increases, for example.

[0021] When the deceleration determination unit 50 determines that the vehicle is

decelerating and the regeneration possibility determination unit 52 determines that regeneration by the motor MG is possible, an engine brake torque calculation unit 56 calculates an engine rotation speed NE from a current gear position of the automatic transmission 16 during vehicle travel and the vehicle speed V detected by the vehicle speed sensor 44, and calculates a current engine brake torque T_{E1} from the engine rotation speed NE. Note that the engine brake torque calculation unit 56 calculates the actual engine brake torque T_{E1} on the basis of the actual engine rotation speed NE from a stored relationship between the engine rotation speed NE and the engine brake torque T_{E1} , which is determined in advance through experiment such that the engine brake torque T_{E1} increases as the engine rotation speed NE increases, for example. Further, the engine brake torque calculation unit 56 determines the current gear position of the automatic transmission 16 from the signal supplied by the electronic control apparatus 40 to the plurality of solenoid control valves in the oil pressure control circuit 26.

[0022] When the deceleration determination unit 50 determines that the vehicle is decelerating and the regeneration possibility determination unit 52 determines that regeneration by the motor MG is possible, a regenerative torque calculation unit 58 calculates an allowable regenerative torque, as a regeneration capacity, T_{MG1} not exceeding a chargeable power W_{in} of the energy storage device 36 from the SOC (%) of the energy storage device 36, detected by the SOC sensor 46. Note that the regenerative torque calculation unit 58 calculates the allowable regenerative torque T_{MG1} on the basis of the actual SOC (%) of the energy storage device 36 from a stored relationship between the SOC (%) and the allowable regenerative torque T_{MG1} , which is determined in advance through experiment such that the allowable regenerative torque T_{MG1} increases as the SOC (%) decreases, for example.

[0023] When the target rotary braking torque T_G has been calculated by the target deceleration control unit 54, the actual engine brake torque T_{E1} has been calculated by the engine brake torque calculation unit 56, and the allowable regenerative torque T_{MG1} has been calculated by the regenerative torque calculation unit 58, a gear position calculation unit 60 calculates a gear position of the automatic transmission 16 to be used during

deceleration on the basis of the calculated target rotary braking torque T_G , actual engine brake torque T_{E1} , and allowable regenerative torque T_{MG1} . More specifically, the gear position calculation unit 60 calculates a target engine brake torque (= target rotary braking torque T_G - allowable regenerative torque T_{MG1}) T_{E1}' from the target rotary braking torque T_G and the allowable regenerative torque T_{MG1} , calculated respectively by the target deceleration control unit 54 and the regenerative torque calculation unit 58, on the basis of Equation (1) below. The gear position calculation unit 60 then compares the calculated target engine brake torque T_{E1}' with the actual engine brake torque T_{E1} calculated by the engine brake torque calculation unit 56, and calculates a gear position of the automatic transmission 16 at which the actual engine brake torque T_{E1} during deceleration approaches the target engine brake torque T_{E1}' . For example, when the target engine brake torque T_{E1}' is smaller than the actual engine brake torque T_{E1} by at least a predetermined amount, a gear position at which a gear position on a high gear side of the current gear position of the automatic transmission 16 is selected, or in other words a gear position at which the current gear position of the automatic transmission 16 is upshifted, is calculated so that the actual engine brake torque T_{E1} during current travel decreases. Conversely, when the target engine brake torque T_{E1}' is larger than the actual engine brake torque T_{E1} by at least a predetermined amount, a gear position at which a gear position on a low gear side of the current gear position of the automatic transmission 16 is selected, or in other words a gear position at which the current gear position of the automatic transmission 16 is downshifted, is calculated so that the actual engine brake torque T_{E1} during current travel increases.

$$\text{target rotary braking torque } T_G = \text{engine brake torque } T_E + \text{regenerative torque } T_{MG} \quad (1)$$

[0024] When the gear position for use during deceleration has been calculated by the gear position calculation unit 60, a regenerative torque calculation unit 58 calculates an engine brake torque T_{E2} obtained at the calculated gear position, and recalculates the regenerative torque T_{MG1}' from the calculated engine brake torque T_{E2} and the target rotary braking torque T_G using Equation (1). In other words, the regenerative torque

calculation unit 58 calculates the regenerative torque (= target rotary braking torque T_G - engine brake torque T_{E2}) $T_{MG1'}$ by inserting the engine brake torque T_{E2} and the target rotary braking torque T_G into Equation (1).

[0025] When the gear position for use during deceleration has been calculated by the gear position calculation unit 60 and the regenerative torque $T_{MG1'}$ has been recalculated by the regenerative torque calculation unit 58 from the gear position calculated by the gear position calculation unit 60, the target deceleration control unit 54 controls engagement and disengagement of the plurality of hydraulic frictional engagement devices in the automatic transmission 16 via the oil pressure control circuit 26 so that the gear position calculated by the gear position calculation unit 60 is established, and controls the regenerative torque T_E of the motor MG so that the regenerative torque $T_{MG1'}$ recalculated by the regenerative torque calculation unit 58 is achieved.

[0026] FIG. 3 is a flowchart illustrating an example of a control operation executed by the electronic control apparatus 40 to control regeneration by the motor MG and a speed change by the automatic transmission 16 during vehicle deceleration.

[0027] First, in step (step is omitted hereafter) S1 corresponding to the deceleration determination unit 50, a determination is made as to whether or not the vehicle is decelerating. When the determination of S1 is negative, the routine is terminated, but when the determination is affirmative, S2 corresponding to the regeneration possibility determination unit 52 is executed. In S2, a determination is made as to whether or not regeneration by the motor MG is possible. When the determination of S2 is negative, the routine is terminated, but when the determination is affirmative, S3 corresponding to the engine brake torque calculation unit 56 is executed.

[0028] In S3, the engine rotation speed NE is calculated from the gear position of the automatic transmission 16 during vehicle travel and the vehicle speed V, and the actual engine brake torque T_{E1} is calculated from the calculated engine rotation speed NE. Next, in S4 corresponding to the regenerative torque calculation unit 58, the allowable regenerative torque T_{MG1} not exceeding the chargeable power W_{in} of the energy storage device 36 is calculated from the SOC (%) of the energy storage device 36.

[0029] Next, in S5 corresponding to the target deceleration control unit 54 and the gear position calculation unit 60, the target rotary braking torque T_G for realizing the target deceleration G required by the driver during vehicle deceleration is calculated, and the target engine brake torque T_{E1}' is calculated from the calculated target rotary braking torque T_G and the allowable regenerative torque T_{MG1} calculated in S4 using Equation (1). The gear position of the automatic transmission 16 for use during deceleration is then calculated such that the actual engine brake torque T_{E1} approaches the calculated target engine brake torque T_{E1}' .

[0030] Next, in S6 corresponding to the target deceleration control unit 54 and the regenerative torque calculation unit 58, the engine brake torque T_{E2} obtained at the gear position calculated in S5 is calculated, and the regenerative torque T_{MG1}' is recalculated using the calculated engine brake torque T_{E2} . Further, in S6, the regenerative torque of the motor MG is controlled so that the recalculated regenerative torque T_{MG1}' is achieved, and engagement and disengagement of the plurality of hydraulic frictional engagement devices in the automatic transmission 16 are controlled via the oil pressure control circuit 26 so that the gear position calculated in S5 is established.

[0031] Furthermore, when, in the flowchart of FIG. 3, the SOC (%) of the energy storage device 36 is comparatively low, for example, such that the allowable regenerative torque T_{MG1} is calculated to be comparatively large in S4, the target engine brake torque T_{E1}' is calculated in S5 to be smaller than the actual engine brake torque T_{E1} during current travel, calculated in S3, and accordingly, a gear position on the high gear side of the current gear position of the automatic transmission 16 is calculated so that the actual engine brake torque T_{E1} approaches the calculated target engine brake torque T_{E1}' . Conversely, when the SOC (%) of the energy storage device 36 is comparatively high, for example, such that the allowable regenerative torque T_{MG1} is calculated to be comparatively small in S4, the target engine brake torque T_{E1}' is calculated in S5 to be larger than the actual engine brake torque T_{E1} during current travel, calculated in S3, and accordingly, a gear position on the low gear side of the current gear position of the automatic transmission 16 is calculated so that the actual engine brake torque T_{E1}

approaches the calculated target engine brake torque T_{E1} '.

[0032] With the electronic control apparatus 40 of the driving apparatus 10 according to this embodiment of the invention, as described above, the target deceleration control unit 54 decelerates the vehicle by selecting a gear position further toward the high gear side of the automatic transmission 16 when the allowable regenerative torque T_{MG1} of the motor MG is large than when the allowable regenerative torque T_{MG1} is small. Since a gear position on the high gear side of the automatic transmission 16 is selected, the actual engine brake torque T_{E1} decreases, and therefore an amount of regeneration performed by the motor MG can be increased correspondingly, leading to an improvement in fuel efficiency. Further, when the allowable regenerative torque T_{MG1} of the motor MG is small, a gear position on the low gear side of the automatic transmission 16 is selected, and therefore the actual engine brake torque T_{E1} increases in accordance with the reduction in the allowable regenerative torque T_{MG1} of the motor MG such that sufficient braking force can be secured in the vehicle. As a result, the deceleration required by the driver when the hybrid vehicle decelerates can be secured, and an improvement in fuel efficiency can be achieved.

[0033] Further, with the electronic control apparatus 40 of the driving apparatus 10 according to this embodiment of the invention, vehicle travel is performed by selecting a gear position further toward the high gear side of the automatic transmission 16 when the SOC (%) of the energy storage device 36 during vehicle deceleration is low than when the SOC (%) is high. Therefore, the amount of regeneration performed by the motor MG can be increased as the SOC (%) of the energy storage device 36 decreases, while the actual engine brake torque T_{E1} can be increased as the SOC (%) of the energy storage device 36 increases. As a result, the deceleration required by the driver when the hybrid vehicle decelerates can be secured favorably while achieving an improvement in fuel efficiency.

[0034] An embodiment of the invention was described in detail above on the basis of the drawings, but the invention may be applied to other embodiments.

[0035] In the driving apparatus 10 according to the above embodiment, the engine 12 and the motor MG are coupled to the drive wheels 22 via the automatic transmission 16

to be capable of transmitting power, but the motor MG may be provided between the automatic transmission 16 and the drive wheels 22, for example. In other words, the invention may be applied to the driving apparatus 10 as long as the driving apparatus 10 includes the engine 12 and the motor MG and the engine 12 is coupled to the drive wheels 22 via the automatic transmission 16 to be capable of transmitting power.

[0036] Further, the engine brake torque calculation unit 56 according to the above embodiment calculates the engine rotation speed NE from the gear position of the automatic transmission 16 during vehicle travel and the vehicle speed V detected by the vehicle speed sensor 44, but the engine rotation speed NE may be measured directly by providing the engine 12 with an engine rotation speed sensor, for example.

[0037] Note that the above embodiments are merely examples, and the invention may be implemented in various modified and amended embodiments on the basis of the knowledge of persons skilled in the art.

CLAIMS:

1. A control apparatus for a hybrid vehicle, the control apparatus comprising:
 - a motor coupled to a drive wheel;
 - an engine coupled to a drive wheel via a transmission;
 - a energy storage device that exchanges power with the motor; and
 - a controller configured to perform a regeneration operation by the motor when the vehicle decelerates, the controller being configured to select, as a gear position of the transmission, a higher gear position as a regeneration capacity permitted in the motor increases while the vehicle decelerates.
2. The control apparatus according to claim 1, wherein the regeneration capacity permitted in the motor is set a higher value as a state of charge of the energy storage device decreases while the vehicle decelerates.

FIG. 1

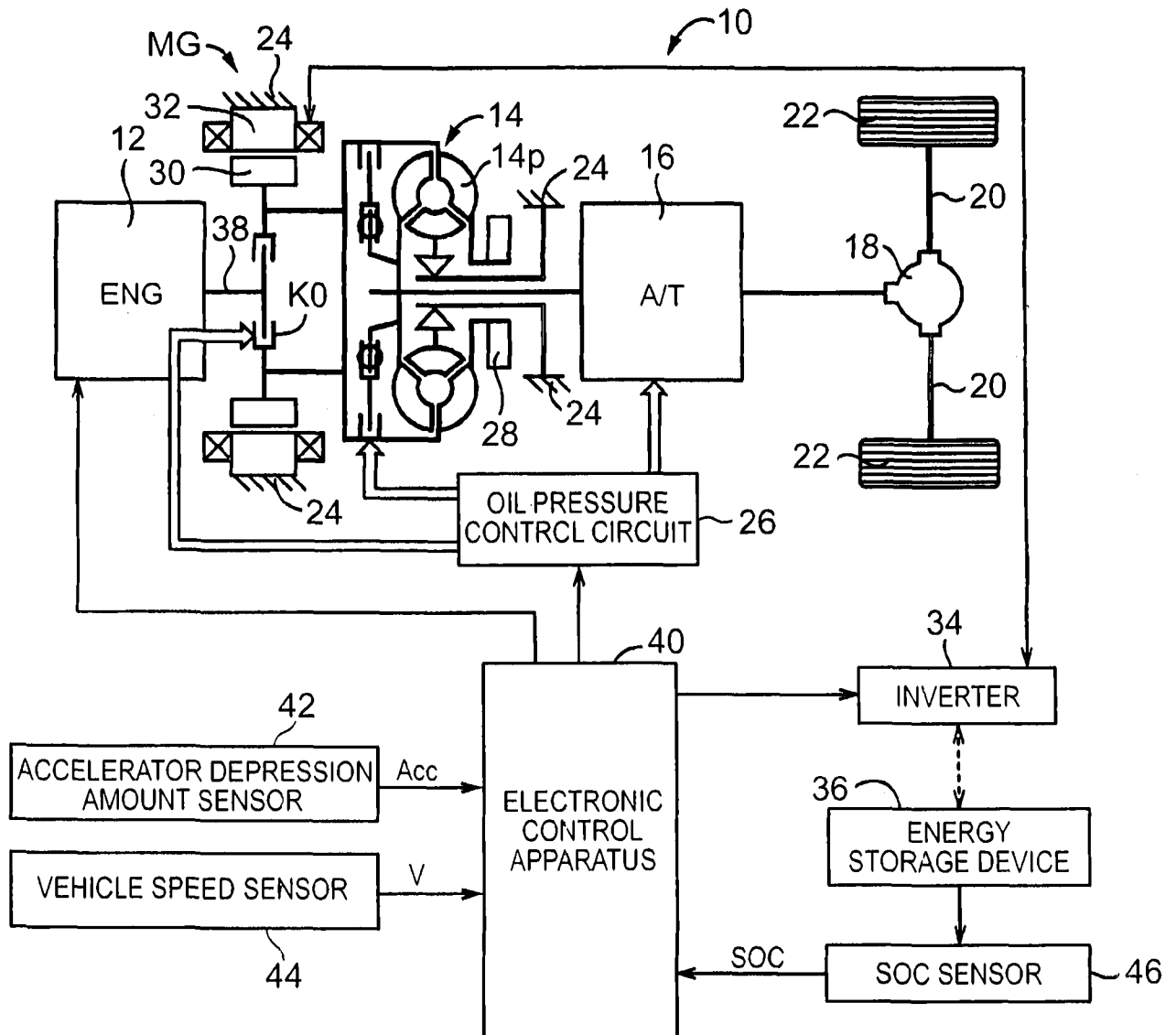


FIG. 2

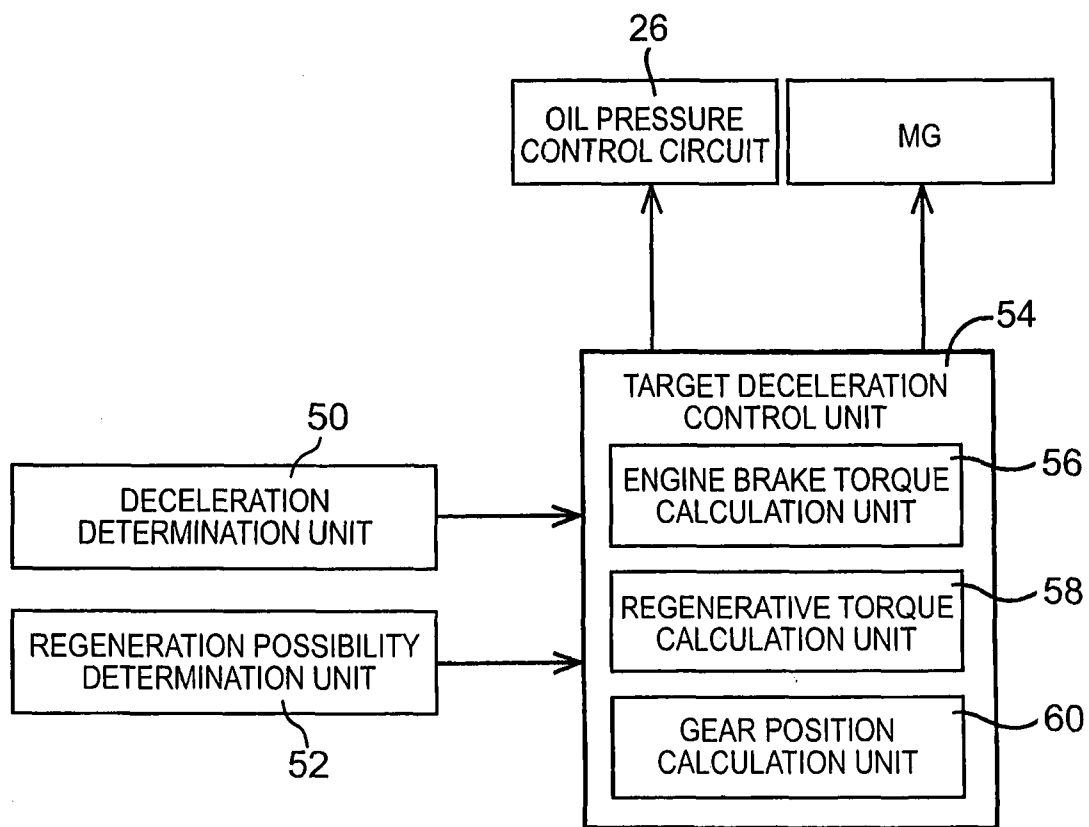
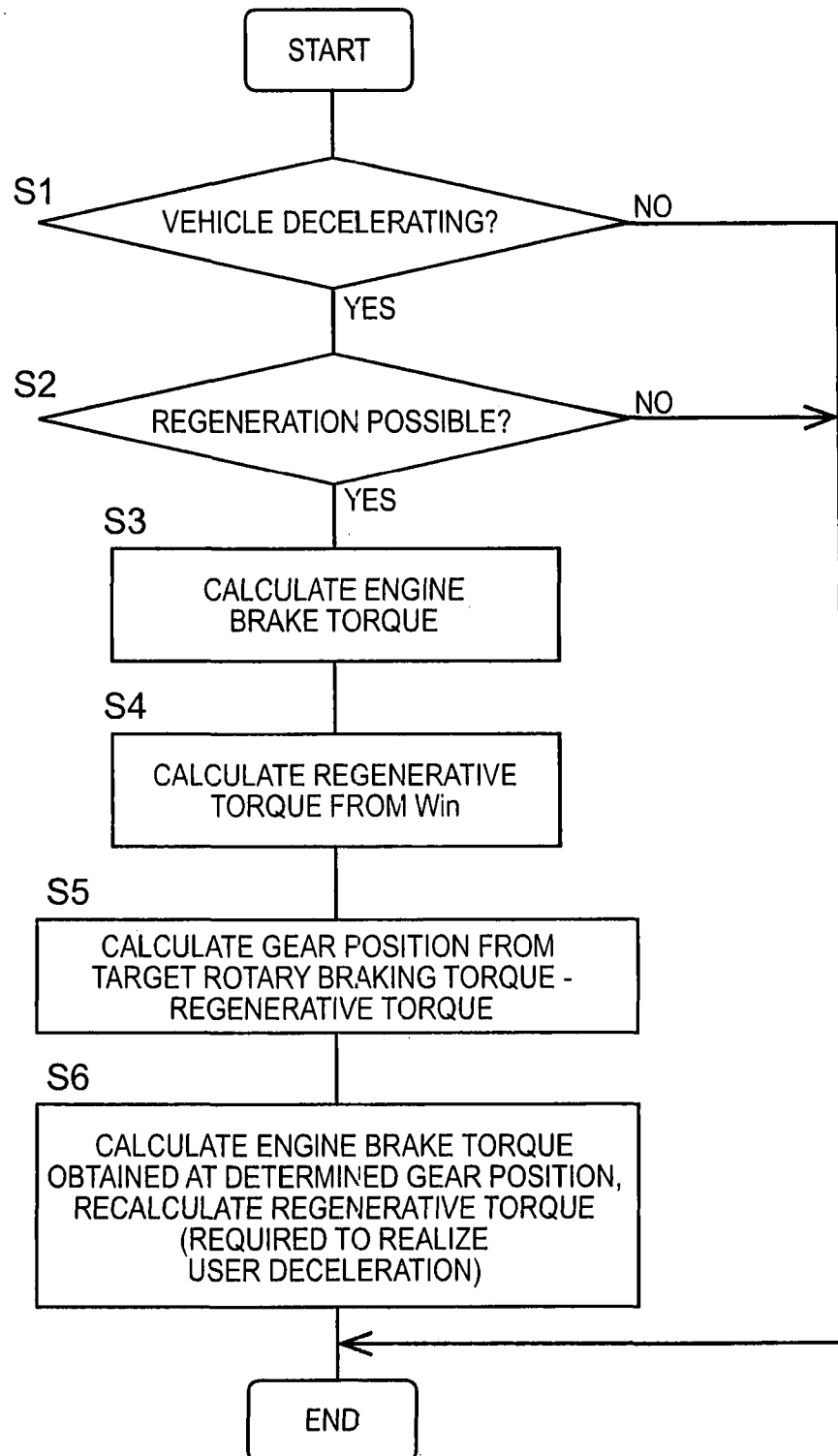


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No

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A. CLASSIFICATION OF SUBJECT MATTER

INV. B60K6/48 B60W10/08 B60W10/115 B60W20/00 B60W30/18
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)

B60K B60W

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 2008/318728 A1 (SOLIMAN IHAB [US] ET AL) 25 December 2008 (2008-12-25) paragraphs [0027] - [0031], [0056] - [0058], [0085] - [0093]; figures 1,4,5,12 -----	1,2
X	WO 2009/157891 A1 (BAYERISCHE MOTOREN WERKE AG [DE]; LEINHOS DIRK CHRISTIAN [US]) 30 December 2009 (2009-12-30) paragraphs [0011] - [0013], [0019] - [0021] the whole document -----	1,2

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

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Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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