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(54) **Torque estimation system and vehicle**

(57) A transmission control system includes a CPU and a RAM. A first equation for calculating an estimated value of a torque (an estimated torque) generated in an engine and a second equation for calculating an inertial torque of a crank of the engine are stored in the RAM. The CPU calculates the estimated torque of the engine from a rotational speed of the engine based on the first equation. Moreover, the CPU calculates the inertial torque of the crank from the rotational speed of the engine in a clutch disconnection state based on the second equation. Then, the CPU corrects the first equation such that the estimated torque of the engine calculated based on the first equation approaches the inertial torque calculated based on the second equation.

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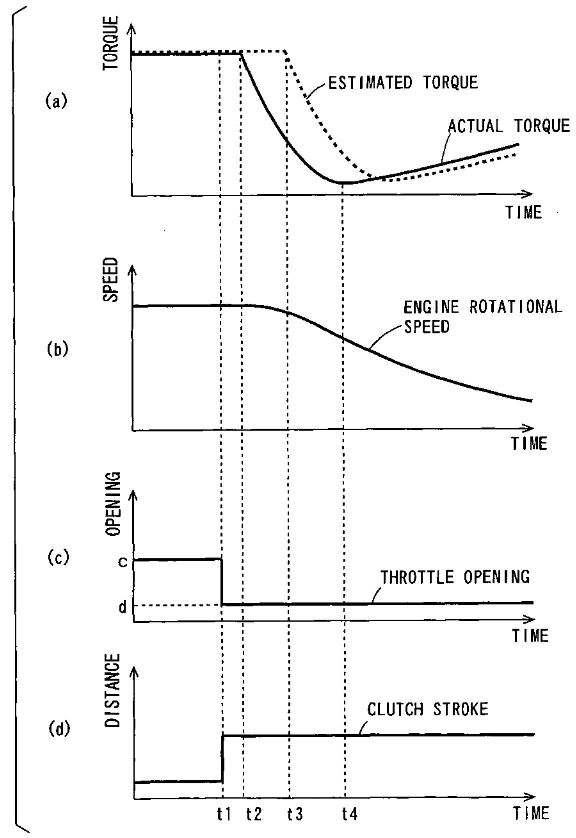

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a torque estimation system that estimates a torque generated in an engine and a vehicle.

Description of the Background Art

[0002] In a vehicle with an automatic or semi-automatic transmission, a torque generated in an engine is estimated with the use of a torque map. Then, an output of the engine after speed change is adjusted based on the estimated torque. This allows for smooth speed change, resulting in improved drivability of the vehicle.

[0003] The foregoing torque map is created based on the torque of the engine measured in a standard driving environment. Therefore, the torque estimated based on the torque map could be greatly different from a torque actually generated in the engine depending on the driving environment of the vehicle.

[0004] In an engine output torque monitor device described in JP 2007-291856 A, for example, an output torque of the engine is estimated to be zero when a difference between the number of input rotations and the number of output rotations of a torque converter is not more than a predetermined value, so that errors in the torque map are corrected.

SUMMARY OF THE INVENTION

[0005] An object of the present invention is to provide a torque estimation system arranged to estimate a torque of an engine at high accuracy and allow for reduction of a vehicle in cost and size and a vehicle including the torque estimation system.

> (1) According to an aspect of the present invention, a torque estimation system arranged to estimate a torque generated in an engine of a vehicle includes a storage arranged to store a first equation for estimating the torque generated in the engine based on a rotational speed of the engine and a second equation for calculating an inertial torque of a crank of the engine based on the rotational speed of the engine, and an arithmetic processor arranged to calculate an estimated torque of the engine based on the first equation, wherein the arithmetic processor calculates the inertial torque of the crank when the torque generated in the engine is not transmitted to a drive wheel based on the second equation, and corrects the first equation such that the estimated torque calculated based on the first equation approaches the inertial torque calculated based on the second equation.
>
> In the torque estimation system, the estimated torque of the engine is calculated from the rotational speed of the engine by the arithmetic processor based on the first equation. The arithmetic processor calculates the inertial torque of the crank from the rotational speed of the engine based on the second equation. Then, the arithmetic processor corrects the first equation such that the estimated torque calculated based on the first equation approaches the inertial torque calculated based on the second equation.
>
> Here, the inertial torque of the crank is calculated when the torque of the engine is not transmitted to the drive wheel in the torque estimation system. In this case, it can be considered that the inertial toque is equivalent to the torque generated in the engine. Accordingly, the first equation is corrected such that the estimated torque of the engine approaches the inertial torque of the crank as described above, thereby allowing a value of the estimated torque calculated based on the first equation to come close to the torque actually generated in the engine.
>
> Moreover, since the inertial torque of the crank is calculated from the rotational speed of the engine based on the second equation, the inertial torque of the crank can be accurately calculated even when the rotational speed of the engine changes in the torque estimation system. Thus, transient characteristics of the inertial torque when the rotational speed of the engine changes can be reflected in correction of the first equation. This allows transient characteristics of the estimated torque calculated based on the first equation to come close to transient characteristics of the torque actually generated in the engine.
>
> Furthermore, the estimated torque of the engine and the inertial torque of the crank are calculated based on the first equation and the second equation that are previously stored in the storage in the torque estimation system. Accordingly, the estimated torque and the inertial torque can be calculated without providing such a device as a torque converter.
>
> As a result, the torque of the engine can be estimated at high accuracy while the vehicle can be reduced in cost and size.
>
> (2) The first equation may include a time constant of a first-order delay element of rising of the torque generated in

the engine (the first order delay element represents the rise of the torque generated in the engine), and the arithmetic processor may correct a time constant of the first-order delay element in the first equation such that a difference between the estimated torque calculated based on the first equation and the inertial torque of the crank calculated based on the second equation is reduced.

In this case, the transient characteristics of the estimated torque calculated based on the first equation can be brought sufficiently close to the transient characteristics of the torque actually generated in the engine.

(3) The first equation may include a dead time of rising of the torque generated in the engine, the arithmetic processor may correct the dead time in the first equation such that a difference between the estimated torque calculated based on the first equation and the inertial torque of the crank calculated based on the second equation is reduced.

In this case, a rising timing of the torque generated in the engine can be estimated at high accuracy based on the first equation.

(4) The first equation may include a first-order delay element and a dead time, the arithmetic processor may correct a time constant of the first-order delay element and the dead time in the first equation such that a difference between the estimated torque calculated based on the first equation and the inertial torque of the crank calculated based on the second equation is reduced, and the dead time is corrected before the time constant is corrected.

In this case, the time constant in the first equation can be corrected while a difference between the dead time of rising of the estimated torque (i.e., the dead time in the first equation) and the dead time of rising of the torque actually generated in the engine is sufficiently decreased, thereby allowing the first equation to be corrected at high accuracy.

(5) The vehicle may include a transmission, the torque estimation system may further include a controller arranged to increase the rotational speed of the engine in the case of down-shifting of the transmission, and the arithmetic processor may correct the first equation in the case of the down-shifting of the transmission.

In this case, the transient characteristics of the torque generated in the engine when the rotational speed of the engine is increased can be sufficiently reflected in the first equation. This sufficiently improves the accuracy of the estimated torque calculated based on the first equation.

(6) The vehicle may include a transmission, the torque estimation system may further include a controller arranged to decrease the rotational speed of the engine in the case of up-shifting of the transmission, and the arithmetic processor may correct the first equation in the case of the up-shifting of the transmission.

In this case, the transient characteristics of the torque generated in the engine when the rotational speed of the engine is decreased can be sufficiently reflected in the first equation. This sufficiently improves the accuracy of the estimated torque calculated based on the first equation.

(7) The vehicle may include a transmitting mechanism arranged to transmit the torque generated in the engine to the drive wheel, and the torque estimation system may further include a controller arranged to control, when the vehicle is stopped, the transmitting mechanism to interrupt transmission of the torque from the engine to the drive wheel and to increase or decrease the rotational speed of the engine.

In this case, since the transmission of the torque from the engine to the drive wheel is interrupted by the controller, the rotational speed of the engine can be changed in a wide range while the vehicle is stopped. Accordingly, the first equation can be corrected in a wide range of engine rotational speeds. This further improves the accuracy of the estimated torque calculated based on the first equation.

(8) The vehicle may include a throttle valve arranged to adjust an amount of air supplied to the engine and a plurality of rotation members arranged to transmit the torque of the crank to the drive wheel, the storage may store a torque map previously created based on a relationship among the rotational speed of the engine, an opening of the throttle valve and the torque generated in the engine, the first equation may be $Tcal=Tmap \cdot e^{-T2 \cdot s}/(1+T1 \cdot s)$, the second equation may be $Tr=J\times(d\omega/dt)$, the Tcal may be the estimated torque, the Tmap may be a torque obtained from the torque map based on the rotational speed of the engine and the throttle opening, the T1 may be a time constant of a first-order delay element of rising of the torque generated in the engine, the T2 may be a dead time of the rising of the torque generated in the engine, and the s may be a Laplacean in the first equation, and the Tr may be the inertial torque of the crank, the J may be moments of inertia of the crank and the rotational member, which is rotated by the torque transmitted from the crank, of the plurality of rotational members, and the ($d\omega/dt$) may be an angular velocity of the crank in the second equation.

In the torque estimation system, the torque map created based on the relationship among the rotational speed of the engine, the opening of the throttle valve and the torque generated in the engine is previously stored in the storage. Then, the arithmetic processor calculates the estimated torque using the first equation of the first-order delay element with the torque Tmap calculated based on the torque map as the gain. In this case, the estimated torque can be calculated based on the torque map previously stored in the storage, thus facilitating calculation of the estimated torque.

In addition, the arithmetic processor calculates the inertial torque of the crank based on the moments of inertia of the crank and the rotation member that is rotated by the torque transmitted from the crank.

Here, the moment of inertia of the rotation member that is rotated by the torque of the engine while the torque of the engine is not transmitted to the drive wheel can be easily obtained by experiments, simulations and so on. Accordingly, the moment of inertia of the rotation member that is easily obtained is used as an element of the second equation, so that the inertial torque of the crank can be easily calculated at high accuracy in the torque estimation system.

(9) According to another aspect of the present invention, a vehicle includes a drive wheel, an engine, a transmitting mechanism arranged to transmit a torque generated by the engine to the drive wheel, and the torque estimation system according to any of the claims 1 to 8.

[0006] In the vehicle, the torque generated by the engine is transmitted to the drive wheel through the transmitting mechanism. This causes the vehicle to drive.

[0007] In addition, the torque estimation system according to the foregoing embodiment is provided in the vehicle. Thus, the estimated torque of the engine is calculated from the rotational speed of the engine by the arithmetic processor based on the first equation. Moreover, the inertial torque of the crank is calculated from the rotational speed of the engine by the arithmetic processor based on the second equation. Then, the first equation is corrected such that the estimated torque calculated based on the first equation approaches the inertial torque calculated based on the second equation.

[0008] Here, the inertial torque of the crank is calculated when the torque of the engine is not transmitted to the drive wheel in the torque estimation system. In this case, it can be considered that the inertial toque is equivalent to the torque generated in the engine. Accordingly, the first equation is corrected such that the estimated torque of the engine approaches the inertial torque of the crank as described above, thereby allowing the value of the estimated torque calculated based on the first equation to come close to the torque actually generated in the engine.

[0009] Moreover, since the inertial torque of the crank is calculated from the rotational speed of the engine based on the second equation, the inertial torque of the crank can be accurately calculated even when the rotational speed of the engine changes in the torque estimation system. Thus, the transient characteristics of the inertial torque when the rotational speed of the engine changes can be reflected in the correction of the first equation. This allows the transient characteristics of the estimated torque calculated based on the first equation to come close to the transient characteristics of the torque actually generated in the engine.

[0010] Furthermore, the estimated torque of the engine and the inertial torque of the crank are calculated based on the first equation and the second equation previously stored in the storage in the torque estimation system. Accordingly, the estimated torque and the inertial torque can be calculated without providing such a device as a torque converter.

[0011] As a result, the torque of the engine can be estimated at high accuracy while the vehicle can be reduced in cost and size.

[0012] According to the present invention, the first equation is corrected such that the estimated torque of the engine approaches the inertial torque of the crank, thereby allowing the value of the estimated torque calculated based on the first equation to come close to the torque actually generated in the engine.

[0013] Moreover, since the inertial torque of the crank is calculated from the rotational speed of the engine based on the second equation, the inertial torque of the crank can be accurately calculated even when the rotational speed of the engine changes. This allows the transient characteristics of the inertial torque when the rotational speed of the engine changes to be reflected in the correction of the first equation. As a result, the transient characteristics of the estimated torque calculated based on the first equation can be brought close to the transient characteristics of the torque actually generated in the engine.

[0014] Furthermore, the estimated torque of the engine and the inertial torque of the crank are calculated based on the first equation and the second equation, so that the estimated torque and the inertial torque can be calculated without providing such a device as a torque converter.

[0015] As a result, the torque of the engine can be estimated at high accuracy while the vehicle can be reduced in cost and size.

[0016] Further, the invention is advantageous as a vehicle including the inventive torque estimation system is reduced in cost and size as no torque converter has to be provided for estimating the actual output of the engine. In addition, when the output torque of the engine changes, its transient characteristics are also reflected in the correction of the torque map so that the torque generated in the engine is estimated at high accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Fig. 1 is a schematic side view of a motorcycle.
Fig. 2 is a diagram showing the structures of a transmission and a shift mechanism.
Fig. 3 is a block diagram showing the structure of a transmission control system.

Fig. 4 is a flowchart showing a control operation of a CPU in gear-shifting.

Fig. 5 is a diagram showing one example of a relationship between an estimated torque and an actual torque.

Fig. 6 is a diagram showing one example of the relationship between the estimated torque and the actual torque.

Fig. 7 is a diagram showing one example of the relationship between the estimated torque and the actual torque.

Fig. 8 is a diagram showing one example of the relationship between the estimated torque and the actual torque.

Fig. 9 is a flowchart showing a correction operation of the CPU.

Fig. 10 is a flowchart showing a correction operation of the CPU.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Hereinafter, description is made of a vehicle including a torque estimation system according to an embodiment of the present invention while referring to the drawings. Note that description is made of a motorcycle as an example of the vehicle in the following paragraphs. In addition, description is made of a semi-automatic transmission control system in which gear-shifting of a transmission is automatically performed based on a shifting operation by a driver as an example of the torque estimation system.

(1) General Structure of Motorcycle

[0019] Fig. 1 is a schematic side view showing a motorcycle according to the present embodiment.

[0020] In the motorcycle 100 of Fig. 1, a head pipe 102 is provided at the front end of a main body frame 101. A front fork 103 is provided at the head pipe 102 so as to be able to swing from side to side. At the lower end of the front fork 103, a front wheel 104 is rotatably supported. A handle 105 is provided at the upper end of the head pipe 102.

[0021] The handle 105 is provided with an accelerator grip 106. An engine 107 is provided at the center of the main body frame 101. A throttle body 108 is attached to an intake port of the engine 107, and an exhaust pipe 109 is attached to an exhaust port of the engine 107. The throttle body 108 is provided with a throttle valve 81.

[0022] A crankcase 110 is attached to the lower portion of the engine 107. A crank 2 (see Fig. 2) of the engine 107 is housed in the crankcase 110.

[0023] A transmission case 111 is provided at the lower portion of the main body frame 101. A transmission 5 (see Fig. 2) and a shift mechanism 6 (see Fig. 2), described below, are provided in the transmission case 111. A shift pedal 112 is provided at the transmission case 111.

[0024] Note that a clutch 3 (see Fig. 2) need not be disconnected by a driver for switching a gear position of the transmission 5 in the present embodiment. In other words, a semi-automatic transmission control system that automatically switches the gear position of the transmission 5 based on a shifting operation by the driver is mounted in the motorcycle 100 according to the present embodiment. Details of the transmission control system will be described below.

[0025] A fuel tank 113 is provided above the engine 107 and a seat 114 is provided to the rear of the fuel tank 113. An ECU (Electronic Control Unit) 50 is provided under the seat 114. A rear arm 115 is connected to the main body frame 101 so as to extend to the rear of the engine 107. A rear wheel 116 and a rear wheel driven sprocket 117 are rotatably held by the rear arm 115. A chain 118 is attached to the rear wheel driven sprocket 117.

(2) Structures of the Transmission and the Shift Mechanism

[0026] Next, description is made of the transmission and the shift mechanism provided in the transmission case 111 of Fig. 1.

[0027] Fig. 2 is a diagram showing the structures of the transmission and the shift mechanism.

[0028] As shown in Fig. 2, the transmission 5 includes a main shaft 5a and a drive shaft 5b. A multi-stage (e.g., five-stage) transmission gears 5c are attached to the main shaft 5a, and a multi-stage transmission gears 5d are attached to the drive shaft 5b.

[0029] The main shaft 5a is coupled to the crank 2 of the engine 107 (Fig. 1) through the clutch 3. The clutch 3 includes a pressure plate 3a, a plurality of clutch disks 3b and a plurality of friction disks 3c. The clutch disks 3b are rotated by a torque transmitted from the crank 2. Moreover, the friction disks 3c are coupled to the main shaft 5a and rotate around the main shaft 5a as a rotation axis.

[0030] The friction disks 3c are biased by the pressure plate 3a in a direction in which the friction disks 3c come into close contact with the clutch disks 3b. A state in which the plurality of clutch disks 3b and the plurality of friction disks 3c are in close contact with one another is referred to as a connection state of the clutch 3, and a state in which the plurality of clutch disks 3b and the plurality of friction disks 3c are separated from one another is referred to as a disconnection state of the clutch 3 in the following description. Although the torque of the crank 2 is transmitted to the main shaft 5a through the clutch disks 3b and the friction disks 3c in the connection state of the clutch 3, the torque of the crank 2 is not transmitted to the main shaft 5a in the disconnection state of the clutch 3.

[0031] A push rod 5e is inserted into the main shaft 5a. One end of the push rod 5e is coupled to the pressure plate 3a, and the other end thereof is coupled to an electric or hydraulic clutch actuator 4.

[0032] In the present embodiment, the push rod 5e is pushed out to the side of the clutch 3 when the clutch actuator 4 is driven by control of the ECU 50. This causes the pressure plate 3a to be pushed to cause the clutch disks 3b and the friction disks 3c to be separated from one another. As a result, the clutch 3 is brought into the disconnection state. Details of the control operation of the ECU 50 will be described below.

[0033] The torque transmitted from the crank 2 to the main shaft 5a when the clutch 3 is in the connection state is transmitted to the drive shaft 5b through the transmission gears 5c and the transmission gears 5d. The chain 118 of Fig. 1 is attached to the drive shaft 5b. The torque of the drive shaft 5b is transmitted to the rear wheel 116 (Fig. 1) through the chain 118 and the rear wheel driven sprocket 117 (Fig. 1). This causes the motorcycle 100 to drive.

[0034] A reduction gear ratio between the main shaft 5a and the drive shaft 5b is determined by combination of the transmission gears 5c and the transmission gears 5d. Moreover, the reduction gear ratio between the main shaft 5a and the drive shaft 5b is changed by moving any transmission gears 5c, 5d of the plurality of transmission gears 5c, 5d. The transmission gears 5c, 5d are moved by operation of the shift mechanism 6.

[0035] The shift mechanism 6 includes a shift cam 6a. A plurality of cam grooves 6b (three in Fig. 2) are formed in the shift cam 6a. A shift fork 6c is attached to each cam groove 6b. The shift cam 6a is connected to an electric or hydraulic shift actuator 7 through a link mechanism that is not shown.

[0036] In the present embodiment, the shift cam 6a is rotated when the shift actuator 7 is driven by control of the ECU 50. This causes each shift fork 6c to move along the cam groove 6b. As a result, any transmission gears 5c, 5d are moved to change the gear position of the transmission 5.

(3) The Transmission Control System

[0037] Next, description is made of the transmission control system of the motorcycle 100.

[0038] Fig. 3 is a block diagram showing the configuration of the transmission control system according to the present embodiment.

[0039] As shown in Fig. 3, the transmission control system 200 according to the present embodiment includes a correction switch SW, an accelerator opening sensor SE1, a throttle sensor SE2, an engine rotational speed sensor SE3, a shift cam rotation angle sensor SE4, a drive shaft rotational speed sensor SE5, a shifting operation detection sensor SE6, the ECU 50, the clutch actuator 4, the shift actuator 7 and a throttle actuator 8.

[0040] The correction switch SW is provided at the handle 105, for example. The correction switch SW will be described below. The accelerator opening sensor SE1 detects an operation amount of the accelerator grip 106 (Fig. 1) (hereinafter referred to as "an accelerator opening") by the driver and applies the detected accelerator opening to the ECU 50. The throttle sensor SE2 detects an opening of the throttle valve 81 (Fig. 1)(hereinafter referred to as "a throttle opening") and applies the detected throttle opening to the ECU 50. The engine rotational speed sensor SE3 detects a rotational speed of the engine 107 (Fig. 1) and applies the detected rotational speed to the ECU 50. Note that the engine rotational speed sensor SE3 detects an angular velocity of the crank 2 (Fig. 2) to detect the rotational speed of the engine 107 in the present embodiment.

[0041] The shift cam rotation angle sensor SE4 detects a rotation angle of a shift cam 6a (Fig. 2) and applies the detected rotation angle to the ECU 50. The drive shaft rotational speed sensor SE5 detects a rotational speed of the drive shaft 5b (Fig. 2) and applies the detected rotational speed to the ECU 50.

[0042] The shifting operation detection sensor SE6 detects a direction in which the shift pedal 112 (Fig. 1) is operated by the driver and applies a signal indicating the detected direction of operation (a signal indicating up-shifting or a signal indicating down-shifting) to the ECU 50. The shifting operation detection sensor SE6 is composed of a potentiometer, a load sensor, a magnetostrictive sensor or the like, for example. Note that the shifting operation detection sensor SE6 outputs the signal with a positive value when an up-shifting operation is detected, and outputs the signal with a negative value when a down-shifting operation is detected, for example.

[0043] The shift actuator 7 is electric or hydraulic, for example, and rotates the shift cam 6a (Fig. 2) by control of the CPU 52, described below. The throttle actuator 8 includes an electric motor, for example, and adjusts the opening of the throttle valve 81 by control of the CPU 52.

[0044] The ECU 50 includes an interface circuit 51, a CPU (central processing unit) 52, a ROM (read only memory) 53, and a RAM (random access memory) 54.

[0045] Output signals of the foregoing sensors SE1 to SE6 are applied to the CPU 52 through the interface circuit 51. The CPU 52 adjusts the output of the engine 107 based on results of detection of the sensors SE1 to SE6, described below. The ROM 53 stores a control program of the CPU 52 and so on. The RAM 54 stores various kinds of data and functions as a processing area of the CPU 52.

(4) Output Control of the Engine by the CPU

[0046] A stationary torque map and a torque estimation physical model are previously stored in the ROM 53 (or the RAM 54) of the ECU 50 in the present embodiment. The stationary torque map expresses a relationship among the rotational speed of the engine 107, the throttle opening and the torque of the engine 107 measured in a standard driving environment. The torque estimation physical model is mathematically expressed by the following equation (1) and stored in the ROM 53 (or the RAM 54).

[0047] In the following equation (1), Tcal is an estimated torque of the engine 107, and Tmap is a torque obtained from the stationary torque map based on the rotational speed of the engine 107 and the throttle opening (hereinafter referred to as "a stationary torque Tmap"). T1 is a time constant of a first-order delay element of the torque generated in the engine 107, T2 is a dead time, and s is a Laplacean.

$$\mathrm{Tcal} = \mathrm{Tmap}\cdot e^{-T2\cdot s}/(1+T1\cdot s) \cdots (1)$$

[0048] Note that the time constant T1 and the dead time T2 in the equation (1) above are stored in the RAM 54 so as to be changed by a correction operation of the CPU 52. Initial values of the time constant T1 and the dead time T2 are calculated by experiments, simulations or the like, and previously stored in the RAM 54 (or the ROM 53). Note that the time constant T1 and the dead time T2 are normalized by a cycle time period of the engine 107 (a time period required for two rotations of the crank 2), for example, and expressed by the product of the cycle time period of the engine 107 and a preset coefficient. In this case, the time constant T1 of the same value and the dead time T2 of the same value can be used regardless of the rotational speed of the engine 107.

[0049] In the present embodiment, the time constant T1 and the dead time T2 are corrected by the CPU 52, so that an error between the estimated torque Tcal calculated based on the equation (1) and the torque actually generated in the engine 107 can be reduced. Details of the correction operation of the CPU 52 will be described below.

(a) Basic Operation in the Output Control

[0050] First, description is made of output adjustment of the engine 107 by the CPU 52 when the shift pedal 112 (Fig. 1) is not operated by the driver.

[0051] In the present embodiment, the CPU 52 controls the throttle actuator 8 based on the accelerator opening detected by the accelerator opening sensor SE1. Thus, the throttle opening is adjusted and the output of the engine 107 is adjusted. Note that a relationship between the accelerator opening and the throttle opening is previously stored in the ROM 53 (or the RAM 54) of the ECU 50.

[0052] The CPU 52 calculates the stationary torque Tmap based on the throttle opening detected by the throttle sensor SE2 and the rotational speed of the engine 107 detected by the engine rotational speed sensor SE3. The CPU 52 calculates the estimated torque Tcal based on the stationary torque Tmap and the equation (1). Then, the CPU 52 controls the throttle actuator 8 based on the estimated torque Tcal.

(b) Output Control in Gear-Shifting

[0053] Next, description is made of the output adjustment of the engine 107 by the CPU 52 when the driver operates the shift pedal 112 for gear-shifting.

[0054] Fig. 4 is a flowchart showing the control operation of the CPU 52 in the gear-shifting.

[0055] As shown in Fig. 4, the CPU 52 first determines based on the output signal of the shifting operation detection sensor SE6 (Fig. 3) whether the driver has performed the shifting operation (Step S1). When the shifting operation has not been performed by the driver, the ECU 50 waits until the shifting operation is performed.

[0056] When the shifting operation is performed by the driver, the CPU 52 disconnects the clutch 3 (Fig. 2) by controlling the clutch actuator 4 (Fig. 2) (Step S2).

[0057] Next, the CPU 52 controls the throttle actuator 8 (Fig. 3) to adjust the throttle opening, thereby increasing or decreasing the rotational speed of the engine 107 (Step S3). Specifically, when the down-shifting operation is performed by the driver during deceleration of the motorcycle 100, the CPU 52 causes the throttle opening to be larger than a value determined based on the accelerator opening, for example. This causes the rotational speed of the engine 107 to increase. When the up-shifting operation is performed by the driver during acceleration of the motorcycle 100, the CPU 52 causes the throttle opening to be smaller than the value determined based on the accelerator opening, for example. This decreases the rotational speed of the engine 107.

[0058] Note that the process of Step S3 prevents the rotational speed of the main shaft 5a (the friction disks 3c (Fig.

2)) and the rotational speed of the clutch disks 3b (Fig. 2) from being greatly different form each other at the time of connection of the clutch 3 in Step S5, described below. Accordingly, an occurrence of a shift shock in the motorcycle 100 is prevented.

[0059] Next, the CPU 52 controls the shift actuator 7 (Fig. 3) to rotate the shift cam 6a (Fig. 2) (Step S4). Thus, the shift forks 6c (Fig. 2) are moved, thereby moving the transmission gears 5c (Fig. 2) or the transmission gears 5d (Fig. 2). As a result, the gear position of the transmission 5 is changed.

[0060] Thereafter, the CPU 52 controls the clutch actuator 4 to connect the clutch 3 (Step S5). In this manner, the gear-shifting of the transmission 5 is finished.

(5) Correction of the Time Constant and the Dead Time

[0061] Next, description is made of a method of correcting the time constant T1 and the dead time T2 in the equation (1).

[0062] In the present embodiment, the CPU 52 performs the correction operation when the shifting operation is performed by the driver or when the correction switch SW (Fig 3) is turned on by the driver.

(a) Correction Operation in the case of the Down-Shifting

[0063] First, description is made of the correction operation performed in the case of the down-shifting.

[0064] In the case of the down-shifting, the CPU 52 calculates an inertial torque Tr of the crank 2 based on the following equation (2) previously stored in the ROM 53 (or the RAM 54). Then, the CPU 52 performs the correction operation, described below, assuming that the calculated inertial torque of the crank 2 as a torque actually generated in the engine 107 (hereinafter referred to as "an actual torque Tr").

$$Tr = J \times (d\omega/dt) \cdots (2)$$

[0065] Note that in the equation (2), J is a moment of inertia of a body of rotation rotated by the engine 107 at the time of disconnection of the clutch 3, and is preset based on experiments, simulations or the like. The moment of inertia J is calculated by adding the moments of inertia of a plurality of torque transmitting members (including the crank 2 and the clutch disks 3b) between the crank 2 (Fig. 2) and the clutch disks 3b (Fig. 2), for example.

[0066] In the equation (2), (dω/dt) is an angular acceleration of the crank 2 in a period during which the clutch 3 is disconnected. The angular acceleration (dω/dt) of the crank 2 is detected by the engine rotational speed sensor SE3.

[0067] Figs. 5 and 6 are diagrams showing examples of a relationship between the estimated torque Tcal calculated based on the equation (1) and the actual torque Tr calculated based on the equation (2). Note that in Figs. 5 and 6, (a) is a graph showing change with time of the actual torque Tr and the estimated torque Tcal, (b) is a graph showing change with time of the rotational speed of the engine 107 detected by the engine rotational speed sensor SE3, (c) is a graph showing change with time of the throttle opening, and (d) is a graph showing change with time of a movement amount of the push rod 5e (Fig. 2) (hereinafter referred to as "the clutch stroke").

[0068] In the example of Fig. 5, the clutch 3 is disconnected and the throttle opening is increased from a value a to a value b at a time point t1. Thereafter, the actual torque Tr is increased at a time point t2 and the estimated torque is increased at a time point t3. In this example, a time period between the time point t1 at which the throttle opening is increased and the time point t2 at which the increase of the actual torque Tr is started is a dead time of the actual torque Tr, and a time period between the time point t1 and the time point t3 at which the increase of the estimated torque Tcal is started is a dead time of the estimated torque Tcal.

[0069] Accordingly, the dead time of the estimated torque Tcal is longer than the dead time of the actual torque Tr in the example of Fig. 5. In such a case, the CPU 52 corrects the dead time T2 of the torque estimation physical model (the equation (1)) such that the dead time of the actual torque Tr and the dead time of the estimated torque Tcal coincide with each other.

[0070] Note that for example, when values of the actual torque Tr and the estimated torque Tcal reach a preset value at given time points, the CPU 52 determines that the foregoing given time points are time points at which the increase of the actual torque Tr and the estimated torque Tcal is started in the present embodiment. The above-mentioned preset value is a value of 3 % to 10 % of a maximum value of the actual torque Tr (a torque value at the time point t4 in Fig. 5), for example. Then, the dead time T2 is corrected such that the time point at which the increase of the actual torque Tr is started and the time point at which the increase of the estimated torque Tcal is started coincide with each other. In this case, it is not determined that the increase of the torques is started unless the values of the actual torque Tr and the estimated torque Tcal attain or exceed the preset value. This prevents erroneous detection of the time points at which the increase of the torques is started.

[0071] Meanwhile, after the throttle opening is increased at the time point t1, the actual torque Tr and the estimated torque Tcal are nearly simultaneously increased at the time pint t2 in the example of Fig. 6. That is, the dead times of the actual torque Tr and the estimated torque Tcal are substantially equal. In the example of Fig. 6, however, the estimated torque Tcal is increased more gently than the actual torque Tr. In such a case, the CPU 52 corrects the time constant T1 of the torque estimation physical model such that a rate of change of the estimated torque Tcal is equal to that of the actual torque Tr.

[0072] In this manner, the time constant T1 and the dead time T2 of the torque estimation physical model are corrected in the case of the down-shifting in the present embodiment. This reduces the error between the estimated torque calculated from the torque estimation physical model and the torque actually generated in the engine 107. Accordingly, the engine 107 can be controlled at high accuracy.

(b) Correction Operation in the case of the Up-Shifting

[0073] Next, description is made of the correction operation performed in the case of the up-shifting.

[0074] In the case of the up-shifting, the CPU 52 calculates the actual torque Tr based on the equation (2) in the same manner as in the down-shifting, and performs the correction operation described below.

[0075] Figs. 7 and 8 are diagrams showing examples of the relationship between the estimated torque Tcal calculated based on the equation (1) and the actual torque Tr calculated based on the equation (2). Note that in Figs. 7 and 8, (a) is a graph showing change with time of the actual torque Tr and the estimated torque Tcal, (b) is a graph showing change with time of the rotational speed of the engine 107 detected by the engine rotational speed sensor SE3, (c) is a graph showing change with time of the throttle opening, and (d) is a graph showing change with time of the clutch stroke.

[0076] Note that the time constant T1 in the equation (1) used in the correction operation in the case of the up-shifting may be different from the time constant T1 in the equation (1) used in the correction operation in the case of the down-shifting. Similarly, the dead time T2 in the equation (1) used in the correction operation in the case of the up-shifting may be different from the dead time T2 in the equation (1) used in the correction operation in the case of the down-shifting.

[0077] In the example of Fig. 7, the clutch 3 is disconnected and the throttle opening is decreased from a value c to a value d at a time point t1. Thereafter, the actual torque Tr is decreased at a time point t2 and the estimated toque is decreased at a time point t3. In this example, a time period between the time point t1 at which the throttle opening is decreased and the time point t2 at which the decrease of the actual torque Tr is started is a dead time of the actual torque Tr, and a time period between the time point t1 and the time point t3 at which the decrease of the estimated torque Tcal is started is a dead time of the estimated torque Tcal.

[0078] Accordingly, the dead time of the estimated torque Tcal is longer than the dead time of the actual torque Tr in the example of Fig. 7. In such a case, the CPU 52 corrects the dead time T2 of the torque estimation physical model (the equation (1)) such that the dead time of the actual torque Tr and the dead time of the estimated torque Tcal coincide with each other.

[0079] Meanwhile, after the throttle opening is decreased at the time point t1, the actual torque Tr and the estimated torque Tcal are nearly simultaneously decreased at the time pint t2 in the example of Fig. 8. That is, the dead times of the actual torque Tr and the estimated torque Tcal are substantially equal. In the example of Fig. 8, however, the estimated torque Tcal is decreased more gently than the actual torque Tr. In such a case, the CPU 52 corrects the time constant T1 of the torque estimation physical model such that a rate of change of the estimated torque Tcal is equal to that of the actual torque Tr.

[0080] In this manner, the time constant T1 and the dead time T2 of the torque estimation physical model are corrected in the case of the up-shifting in the present embodiment. This reduces the error between the estimated torque calculated from the torque estimation physical model and the torque actually generated in the engine 107. Accordingly, the engine 107 can be controlled at high accuracy.

(c) Correction Operation by the Correction Switch SW

[0081] Similarly to the cases of the down-shifting and the up-shifting, the CPU 52 corrects the time constant T1 and the dead time T2 when a maintenance operator turns on the correction switch SW.

[0082] Specifically, the CPU 52 disconnects the clutch 3 and increases the throttle opening to increase or decrease the rotational speed of the engine 107 by 1000 rpm, for example. Thereafter, the CPU 52 calculates the actual torque Tr and the estimated torque Tcal when the rotational speed of the engine 107 is increased or decreased by 1000 rpm in the same manner as that described above. Then, the CPU 52 corrects the time constant T1 and the dead time T2 of the torque estimation physical model if the actual torque Tr and the estimated torque Tcal are different from each other.

[0083] The CPU 52 performs the foregoing operation for every 1000 rpm in a range of the rotational speed of the engine 107 from 1000 rpm to 9000 rpm, for example. This allows the time constant T1 and the dead time T2 of the torque estimation physical model to be corrected to suitable values in the wide range of rotational speeds of the engine 107.

As a result, the engine 107 can be controlled at higher accuracy.

[0084] Note that in the case of setting the gear position of the transmission 5 in a neutral position, the time constant T1 and the dead time T2 when the correction switch SW is turned on may be corrected with the clutch 3 being connected. In this case, the moment of inertia J in the equation (2) is calculated by adding the moments of inertia of the plurality of torque transmitting members between the crank 2 (Fig. 2) and the transmission gears 5c (Fig. 2).

(d) Control Flow

[0085] Figs. 9 and 10 are flowcharts showing the correction operation of the CPU 52.

[0086] As shown in Fig. 9, the CPU 52 first determines whether the motorcycle 100 is running based on a detected value of the drive shaft rotational speed sensor SE5 (Step S11).

[0087] When the motorcycle 100 is running, the CPU 52 determines whether the shifting operation is performed by the driver based on the output signal of the shifting operation detection sensor SE6 (Step S12). When the shifting operation is not performed by the driver, the CPU 52 returns to the process of Step S11.

[0088] When the shifting operation is performed by the driver, the CPU 52 waits until the gear-shifting of the transmission 5 is finished (Step S13). Note that in Step S13, it is determined that the gear-shifting is completed when the clutch stroke attains not more than a preset value, for example. The clutch stroke may be calculated based on a control amount applied from the CPU 52 to the clutch actuator 4 (Fig. 2), or may be calculated by providing a detection sensor that detects the movement amount of the push rod 5e (Fig. 2), for example.

[0089] After completion of the gear-shifting, the CPU 52 calculates the actual torque Tr during disconnection of the clutch 3 and the dead time of the actual torque Tr (Step S14). Note that the dead time of the actual torque Tr is calculated as a time period from the increase or decrease of the throttle opening to the start of the increase or decrease of the actual torque Tr (the time period between the time point t1 and the time point t2 in Fig. 5), for example.

[0090] Next, the CPU 52 calculates a difference between the dead time of the actual torque Tr calculated in Step S14 and the dead time T2 of the torque estimation physical model (see the equation (1)) (Step S15).

[0091] Next, the CPU 52 determines whether the difference calculated in Step S15 is not more than a preset first threshold value (T2/2, for example) (Step S16). When the difference calculated in Step S15 is not more than the first threshold value, the CPU 52 corrects the dead time T2 of the torque estimation physical model to the dead time calculated in Step S14 (Step S17).

[0092] When the difference calculated in Step S15 is larger than the first threshold value, the CPU 52 proceeds to the subsequent process with no correction of the dead time T2 of the torque estimation physical model. Note that the process of Step S15 prevents the dead time of the actual torque Tr from being reflected in the correction of the dead time T2 of the torque estimation physical model even when the value of the actual torque Tr is erroneously calculated due to measurement failure and so on. Accordingly, the engine 107 can be controlled at higher accuracy.

[0093] Next, the CPU 52 calculates the time constant of the first-order delay element of the actual torque Tr calculated in Step S14 (Fig. 9) as shown in Fig. 10 (Step S18). Note that in Step S18, the time constant is calculated with the maximum value of the actual torque Tr (the torque value at the time point t4 in Fig. 5) as the gain of the first-order delay element in the down-shifting, and the time constant is calculated with the minimum value of the actual torque Tr (the torque value at the time point t4 in Fig. 7) as the gain of the first-order delay element in the up-shifting, for example.

[0094] Next, the CPU 52 calculates a difference between the time constant of the first-order delay element of the actual torque Tr calculated in Step S18 and the time constant T1 (see the equation (1)) of the torque estimation physical model (the corrected torque estimation physical model if the dead time T2 is corrected in Step S17 (Fig. 9)) (Step S19).

[0095] Next, the CPU 52 determines whether the difference calculated in Step S19 is not more than a preset second threshold value (T1/2, for example) (Step S20). When the difference calculated in Step S19 is not more than the second threshold value, the CPU 52 corrects the time constant T1 of the torque estimation physical model to the time constant calculated in Step S18 (Step S21).

[0096] When the difference calculated in Step S20 is larger than the second threshold value, the CPU 52 finishes the correction of the torque estimation physical model with no correction of the time constant T1 of the torque estimation physical model. Note that the process of Step S20 prevents the time constant of the first-order delay element of the actual torque Tr from being reflected in the correction of the time constant T1 of the torque estimation physical model even when the value of the actual torque Tr is erroneously calculated due to measurement failure and so on. Accordingly, the engine 107 can be controlled at higher accuracy.

[0097] As shown in Fig. 9, when it is determined in Step S11 that the motorcycle 100 is not running, the CPU 52 determines whether the correction switch SW is turned on (Step S22). When the correction switch SW is not turned on, the CPU 52 returns to the process of Step S11.

[0098] When the correction switch SW is turned on, the CPU 52 controls the clutch actuator 4 and the shift actuator 7 to disconnect the clutch 3 and adjust the throttle opening, thereby increasing or decreasing the rotational speed of the engine 107 (Step S23). Thereafter, the same processes as Steps S14 to S21 are performed, so that the time constant

T1 and the dead time T2 of the torque estimation physical model are corrected.

[0099] Note that the rotational speed of the engine 107 is increased or decreased by 1000 rpm, for example, in Step S23 in the present embodiment. Then, the actual torque Tr is calculated for each change of the rotational speed by 1000 rpm, and the time constant T1 and the dead time T2 of the torque estimation physical model are corrected.

(6) Effects of the Present Embodiment

[0100] In the present embodiment, the time constant T1 and the dead time T2 of the torque estimation physical model are corrected such that transient response characteristics of the torque calculated based on the torque estimation physical model approach transient response characteristics of the torque actually generated in the engine 107 in the gear-shifting of the transmission 5. Accordingly, the engine 107 can be controlled at high accuracy based on the torque estimation physical model.

[0101] The time constant T1 is corrected after the dead time T2 is corrected in the present embodiment. In this case, the time constant T1 can be corrected while the dead time of the actual torque Tr and the dead time T2 of the torque estimation physical model are substantially equal to each other, thus allowing the correction of the torque estimation physical model to be performed at high accuracy.

[0102] The torque estimation physical model is corrected while the motorcycle 100 is actually running, thus allowing the transient response characteristics of the torque calculated based on the torque estimation physical model to easily come close to the transient response characteristics of the torque actually generated in the engine 107 at high accuracy in the present embodiment.

[0103] In addition, the correction switch SW is turned on by the maintenance operator while the motorcycle 100 is stopped, so that the torque estimation physical model can be corrected in the wide range of rotational speeds of the engine 107 in the present embodiment.

[0104] As a result, the torque generated in the engine 107 can be estimated at high accuracy based on the torque estimation physical model.

(7) Other Embodiments

(a) Other Examples of the Correction Method

[0105] While the rotational speed of the engine 107 is increased or decreased by 1000 rpm to correct the torque estimation physical model when the correction switch SW is turned on by the maintenance operator in the foregoing embodiment, the increase or decrease of the rotational speed of the engine 107 is not limited to the foregoing example. For example, the rotational speed of the engine 107 may be increased or decreased by less than 1000 rpm (500 rpm, for example) or larger than 1000 rpm in the correction of the torque estimation physical model.

(b) Other Examples of the Motorcycle

[0106] While the shift pedal 112 is provided for the shifting operation by the driver in the foregoing embodiment, a shift switch may be provided at the handle 105 for detecting the shifting operation by the driver. In this case, the driver operates the shift switch to easily perform the gear-shifting of the transmission 5.

[0107] While description is made of the motorcycle 100 as one example of the vehicle in the foregoing embodiment, another vehicle such as a three-wheeled motor vehicle and a four-wheeled motor vehicle may be applied.

(c) Other Examples of the Transmission Control System

[0108] While description is made of the semi-automatic transmission control system 200 that automatically performs the gear-shifting of the transmission 5 based on the shifting operation by the driver in the foregoing embodiment, the present invention can be applied to a full automatic transmission control system.

[0109] In the full automatic transmission control system, up-shifting control and down-shifting control may be started based on the torque calculated from the torque map, for example.

[0110] While the rotational speed of the engine 107 is adjusted by adjusting the throttle opening in the foregoing embodiment, the rotational speed of the engine 107 may be adjusted by adjusting an ignition timing of an air-fuel mixture or an amount of injected fuel in the engine 107. Note that the CPU 52 can control an ignition plug, not shown, to adjust the ignition timing of the air-fuel mixture. Moreover, the CPU 52 can control a fuel injector, not shown, to adjust the amount of injected fuel.

[0111] While the one CPU 52 calculates the estimated torque, corrects the torque estimation physical model, and adjusts the output of the engine 107 in the foregoing embodiment, these operations may be performed by a plurality of

CPUs 52.

(8) Correspondences between Elements in the Claims and Parts in Embodiments

[0112] In the following paragraph, non-limiting examples of correspondences between various elements recited in the claims below and those described above with respect to various preferred embodiments of the present invention are explained.

[0113] In the foregoing embodiments, the equation (1) is an example of a first equation, the equation (2) is an example of a second equation, the RAM 54 or the ROM 53 are examples of a storage, the CPU 52 is an example of an arithmetic processor and a controller, the rear wheel 116 is an example of a drive wheel, the clutch 3, the clutch actuator 4, the transmission 5, the shift mechanism 6 and the shift actuator 7 are examples of a transmitting mechanism, the clutch disk 3b, the friction disk 3c, the main shaft 5a, the drive shaft 5b, the transmission gear 5c and the transmission gear 5d are examples of a plurality of rotation members.

[0114] As each of various elements recited in the claims, various other elements having configurations or functions described in the claims can be also used.

Claims

1. A torque estimation system arranged to estimate a torque generated in an engine of a vehicle, comprising:

a storage arranged to store a first equation for estimating the torque generated in the engine based on a rotational speed of the engine and a second equation for calculating an inertial torque of a crank of the engine based on the rotational speed of the engine; and
an arithmetic processor arranged to calculate an estimated torque of the engine based on the first equation, wherein
the arithmetic processor is arranged to calculate the inertial torque of the crank based on the second equation when the torque generated in the engine is not transmitted to a drive wheel, and to correct the first equation such that the estimated torque calculated based on the first equation approaches the inertial torque calculated based on the second equation.

2. The torque estimation system according to claim 1, wherein
the first equation includes a time constant of a first-order delay element of a rise of the torque generated in the engine, and
the arithmetic processor is arranged to correct the time constant of the first-order delay element in the first equation such that a difference between the estimated torque calculated based on the first equation and the inertial torque of the crank calculated based on the second equation is reduced.

3. The torque estimation system according to claim 1 or 2, wherein
the first equation includes a dead time of a rise of the torque generated in the engine,
the arithmetic processor is arranged to correct the dead time in the first equation such that a difference between the estimated torque calculated based on the first equation and the inertial torque of the crank calculated based on the second equation is reduced.

4. The torque estimation system according to claim 1, wherein
the first equation includes a time constant of a first-order delay element and a dead time,
the arithmetic processor is arranged to correct the time constant of the first-order delay element and the dead time in the first equation such that a difference between the estimated torque calculated based on the first equation and the inertial torque of the crank calculated based on the second equation is reduced, and
the dead time is corrected before the time constant is corrected.

5. The torque estimation system according to any of claims 1 to 4, wherein the vehicle includes a transmission,
the torque estimation system further includes a controller arranged to increase the rotational speed of the engine in the case of down-shifting of the transmission, and
the arithmetic processor is arranged to correct the first equation in the case of the down-shifting of the transmission.

6. The torque estimation system according to any of claims 1 to 4, wherein the vehicle includes a transmission,
the torque estimation system further includes a controller arranged to decrease the rotational speed of the engine

in the case of up-shifting of the transmission, and
the arithmetic processor is arranged to correct the first equation in the case of the up-shifting of the transmission.

7. The torque estimation system according to any of claims 1 to 4, wherein
the vehicle includes a transmitting mechanism arranged to transmit the torque generated in the engine to the drive wheel, and
the torque estimation system further includes a controller arranged to control, when the vehicle is stopped, the transmitting mechanism to interrupt transmission of the torque from the engine to the drive wheel and to increase or decrease the rotational speed of the engine.

8. The torque estimation system according to any of claims 1 to 7, wherein
the vehicle includes a throttle valve arranged to adjust an amount of air supplied to the engine and a plurality of rotation members arranged to transmit the torque of the crank to the drive wheel,
the storage is arranged to store a torque map previously created based on a relationship among the rotational speed of the engine, an opening of the throttle valve and the torque generated in the engine,

$$\text{the first equation is } Tcal = Tmap \cdot e^{-T2 \cdot s}/(1+T1 \cdot s),$$

$$\text{the second equation is } Tr = J \times (d\omega/dt),$$

the Tcal is the estimated torque, the Tmap is a torque obtained from the torque map based on the rotational speed of the engine and the throttle opening, the T1 is a time constant of a first-order delay element of a rise of the torque generated in the engine, the T2 is a dead time of the rising of the torque generated in the engine, and the s is a Laplacean in the first equation, and
the Tr is the inertial torque of the crank, the J is moments of inertia of the crank and the rotational member, which is rotated by the torque transmitted from the crank, of the plurality of rotational members, and the ($d\omega/dt$) is an angular velocity of the crank in the second equation.

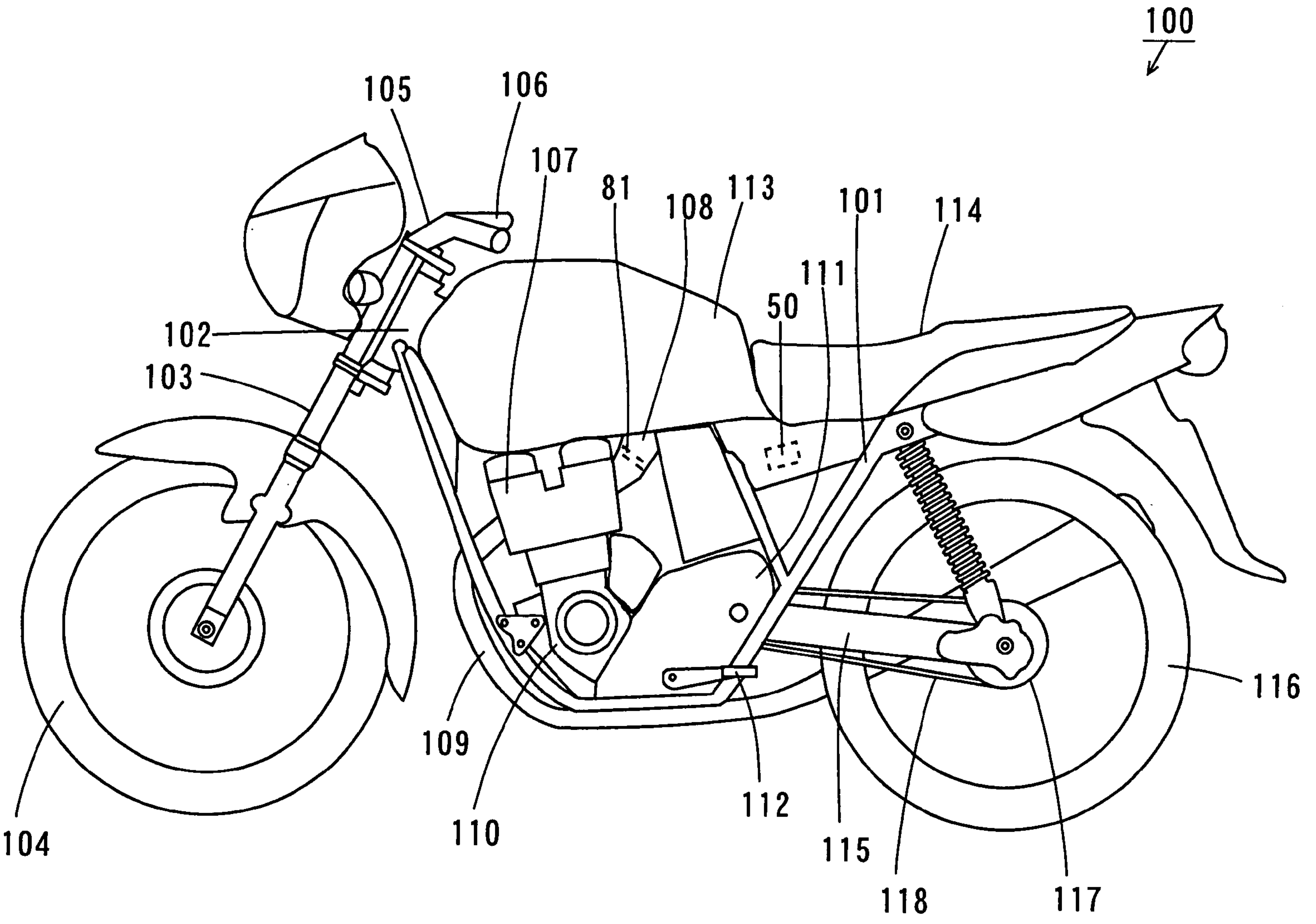
9. A vehicle comprising:

a drive wheel;
an engine;
a transmitting mechanism arranged to transmit a torque generated by the engine to the drive wheel, and
the torque estimation system according to any of claims 1 to 8.

10. A method for estimating a torque generated in an engine of a vehicle on the basis of a first equation for estimating the torque generated in the engine based on a rotational speed of the engine and a second equation for calculating an inertial torque of a crank of the engine based on the rotational speed of the engine, the method comprising:

calculating the inertial torque of the crank based on the second equation when the torque generated in the engine is not transmitted to a drive wheel;
correcting the first equation such that the estimated torque calculated based on the first equation approaches the inertial torque calculated based on the second equation; and
calculating an estimated torque of the engine based on the corrected first equation.

F I G. 1


100
105
106
107
81
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101
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F I G. 2

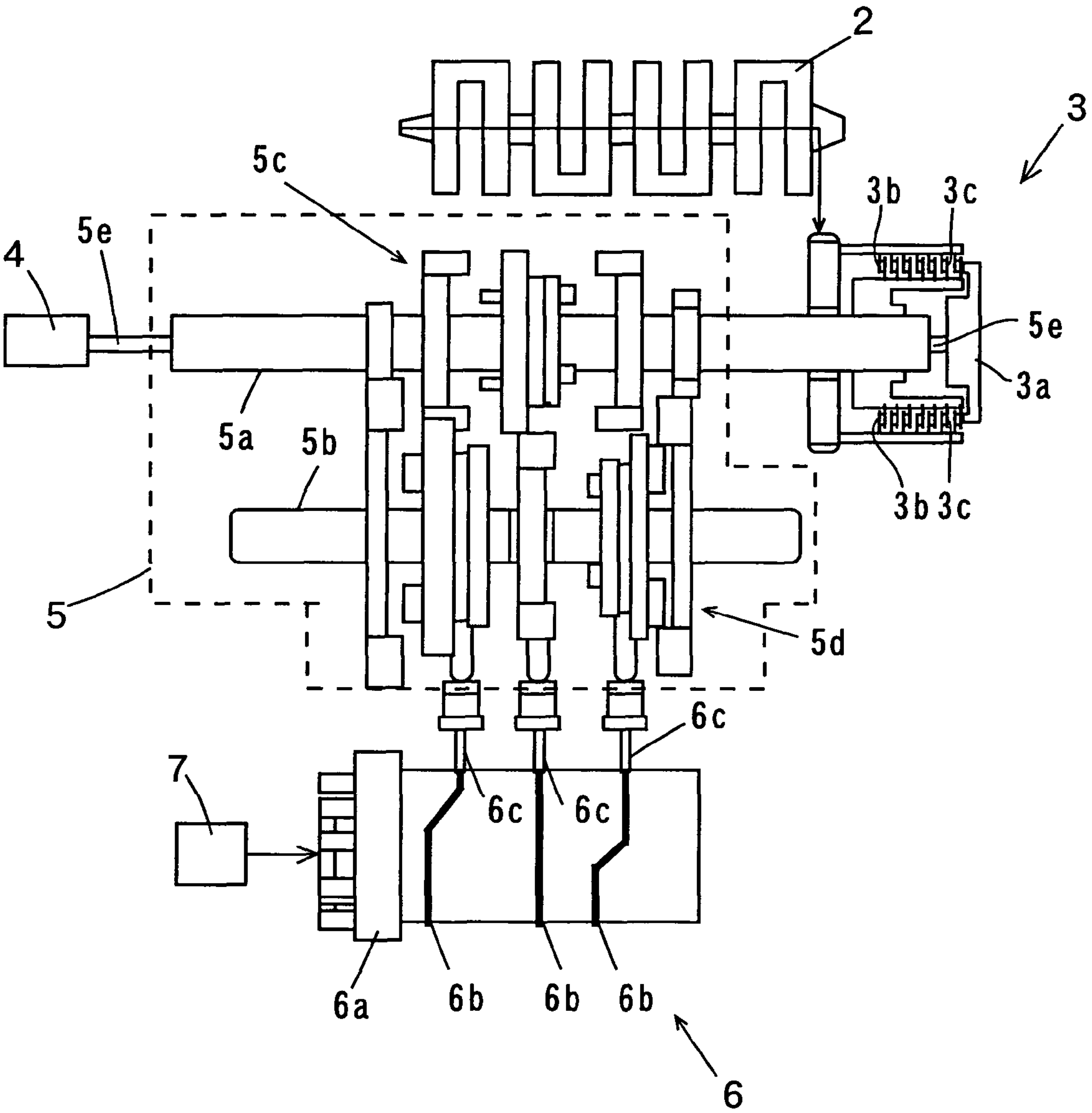


FIG. 3

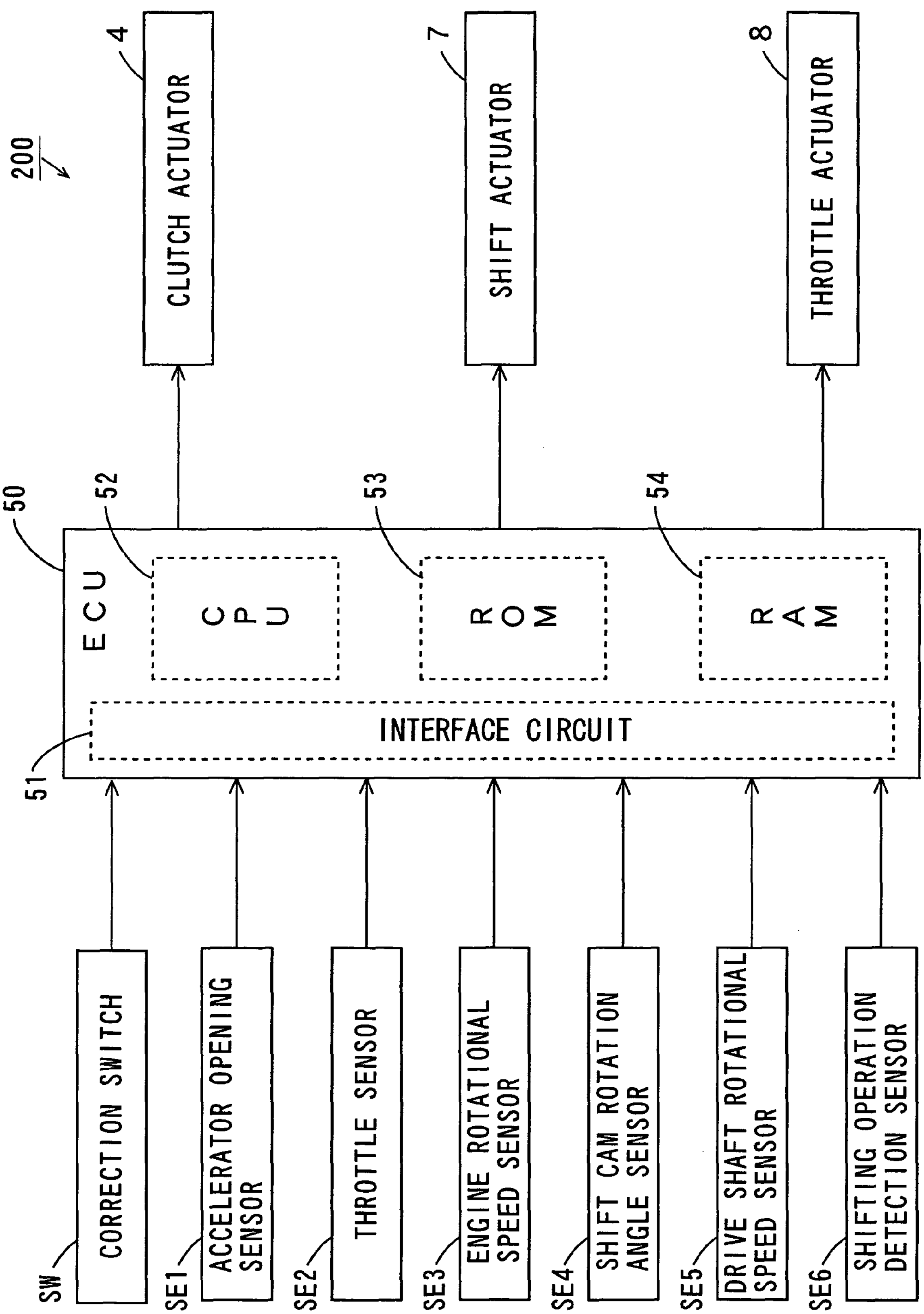

200
4
CLUTCH ACTUATOR
7
SHIFT ACTUATOR
8
THROTTLE ACTUATOR
50
ECU
52
CPU
53
ROM
54
RAM
INTERFACE CIRCUIT
51
SW
CORRECTION SWITCH
SE1
ACCELERATOR OPENING SENSOR
SE2
THROTTLE SENSOR
SE3
ENGINE ROTATIONAL SPEED SENSOR
SE4
SHIFT CAM ROTATION ANGLE SENSOR
SE5
DRIVE SHAFT ROTATIONAL SPEED SENSOR
SE6
SHIFTING OPERATION DETECTION SENSOR

FIG. 4

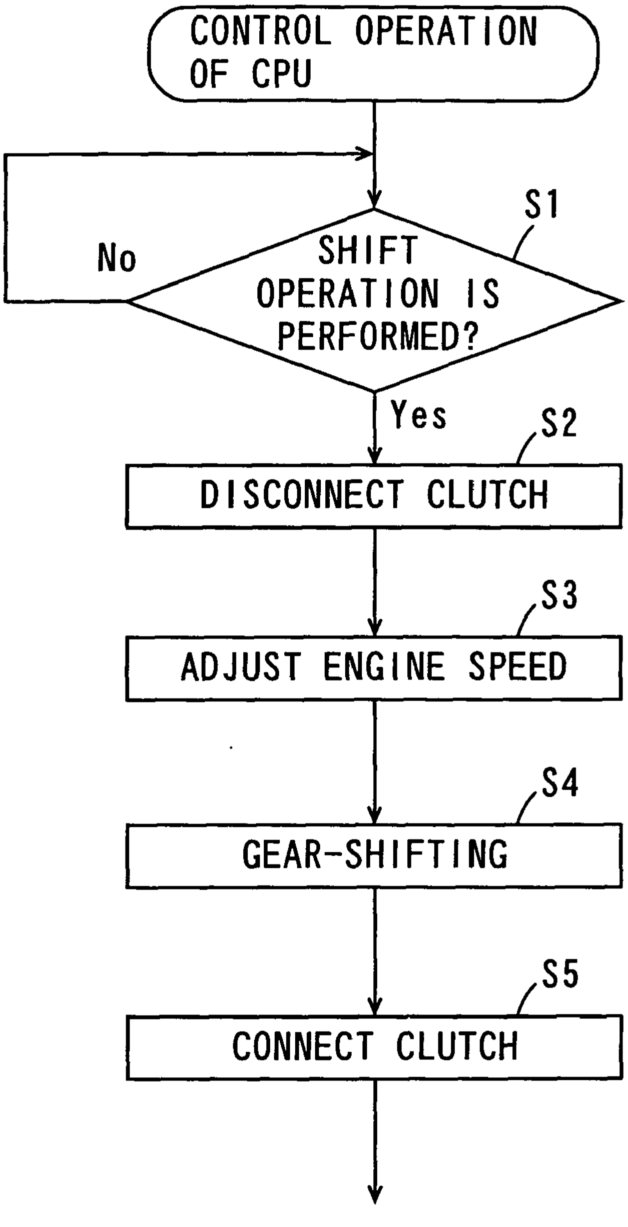
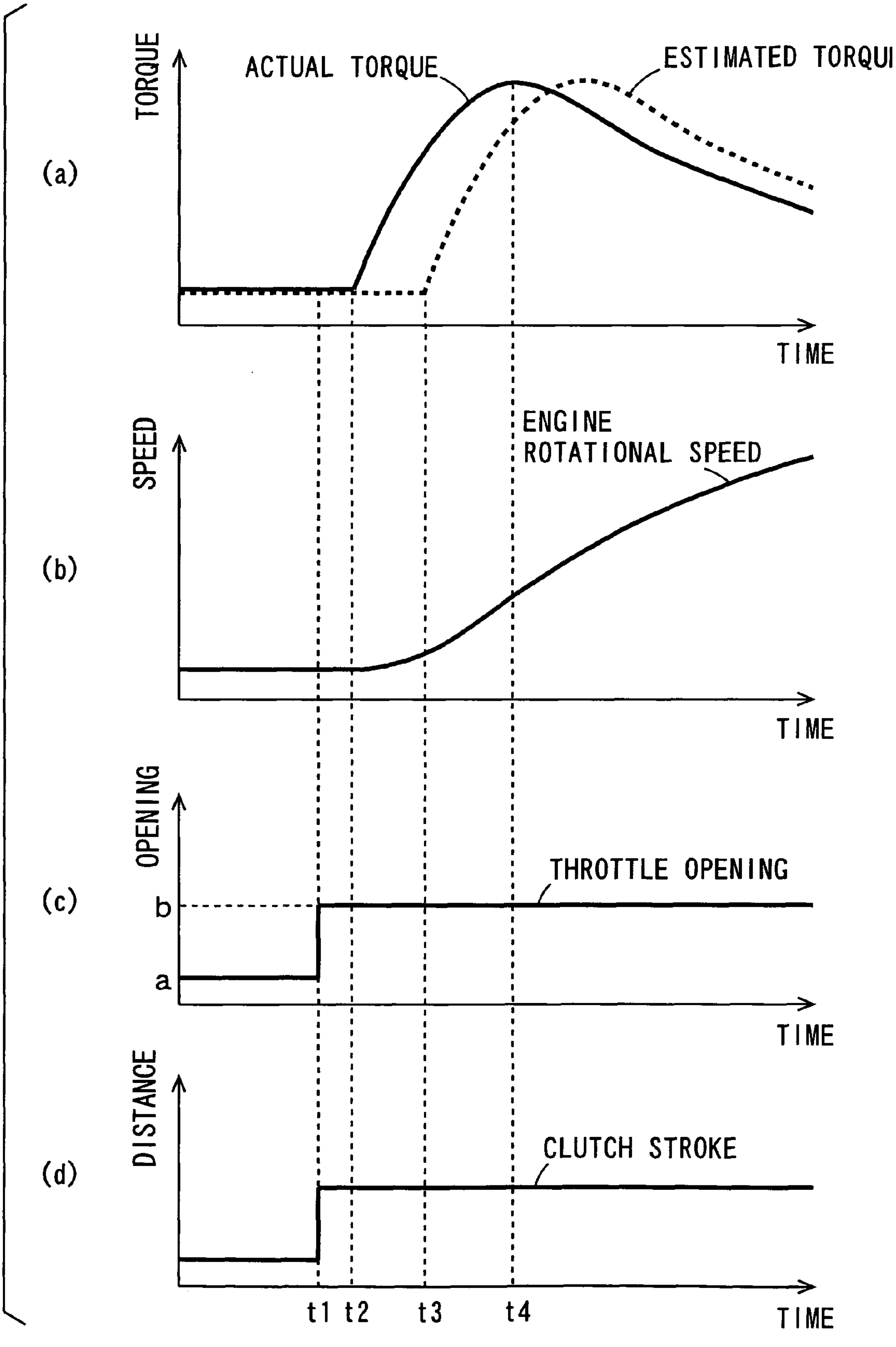

CONTROL OPERATION OF CPU
S1
SHIFT OPERATION IS PERFORMED?
No
Yes
S2
DISCONNECT CLUTCH
S3
ADJUST ENGINE SPEED
S4
GEAR-SHIFTING
S5
CONNECT CLUTCH

FIG. 5


(a)
TORQUE
ACTUAL TORQUE
ESTIMATED TORQUI
TIME
(b)
SPEED
ENGINE ROTATIONAL SPEED
TIME
(c)
OPENING
b
a
THROTTLE OPENING
TIME
(d)
DISTANCE
CLUTCH STROKE
t1
t2
t3
t4
TIME

F I G. 6

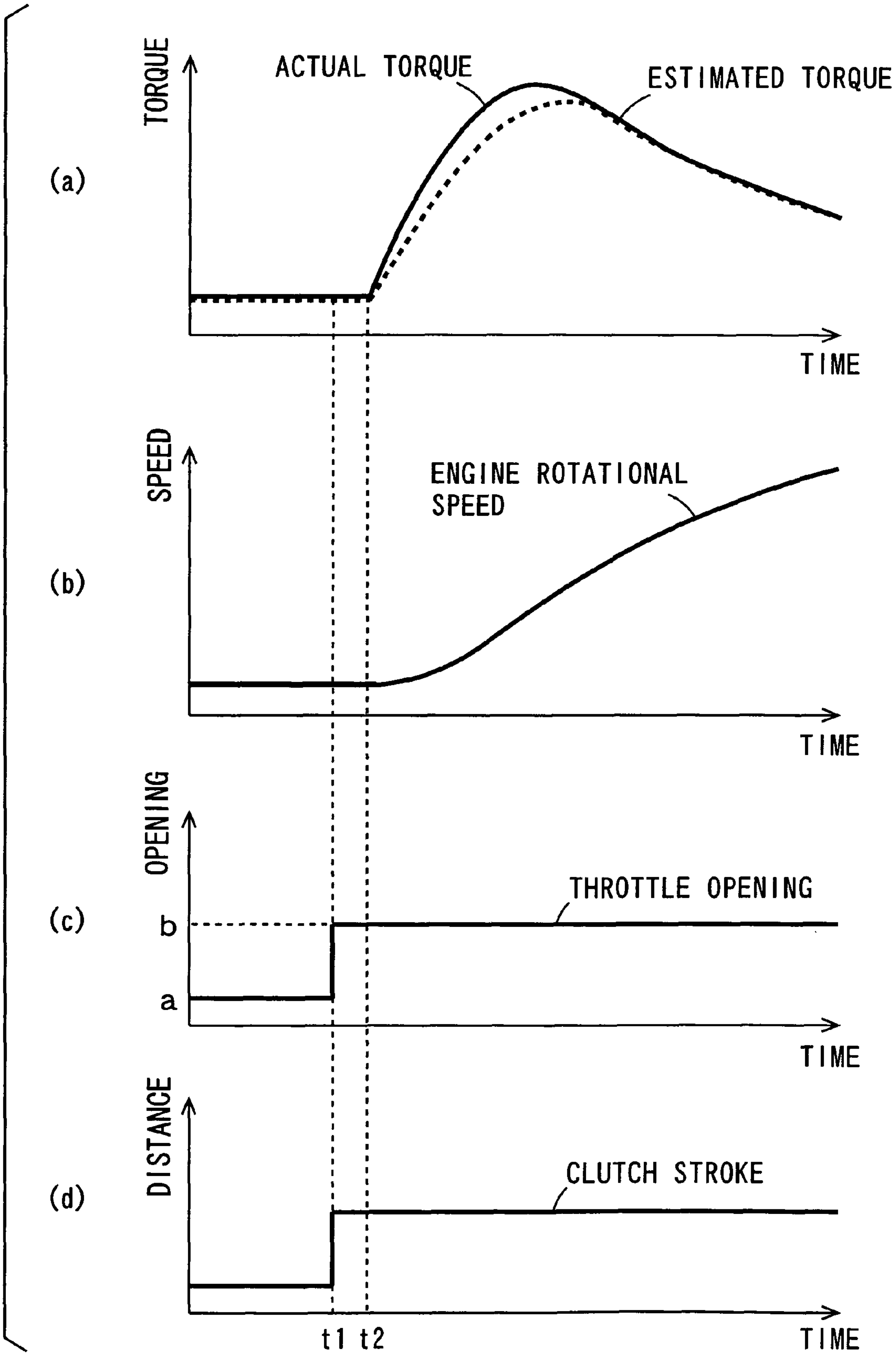

(a)
TORQUE
ACTUAL TORQUE
ESTIMATED TORQUE
TIME
(b)
SPEED
ENGINE ROTATIONAL SPEED
TIME
(c)
OPENING
b
a
THROTTLE OPENING
TIME
(d)
DISTANCE
CLUTCH STROKE
t1 t2
TIME

FIG. 7

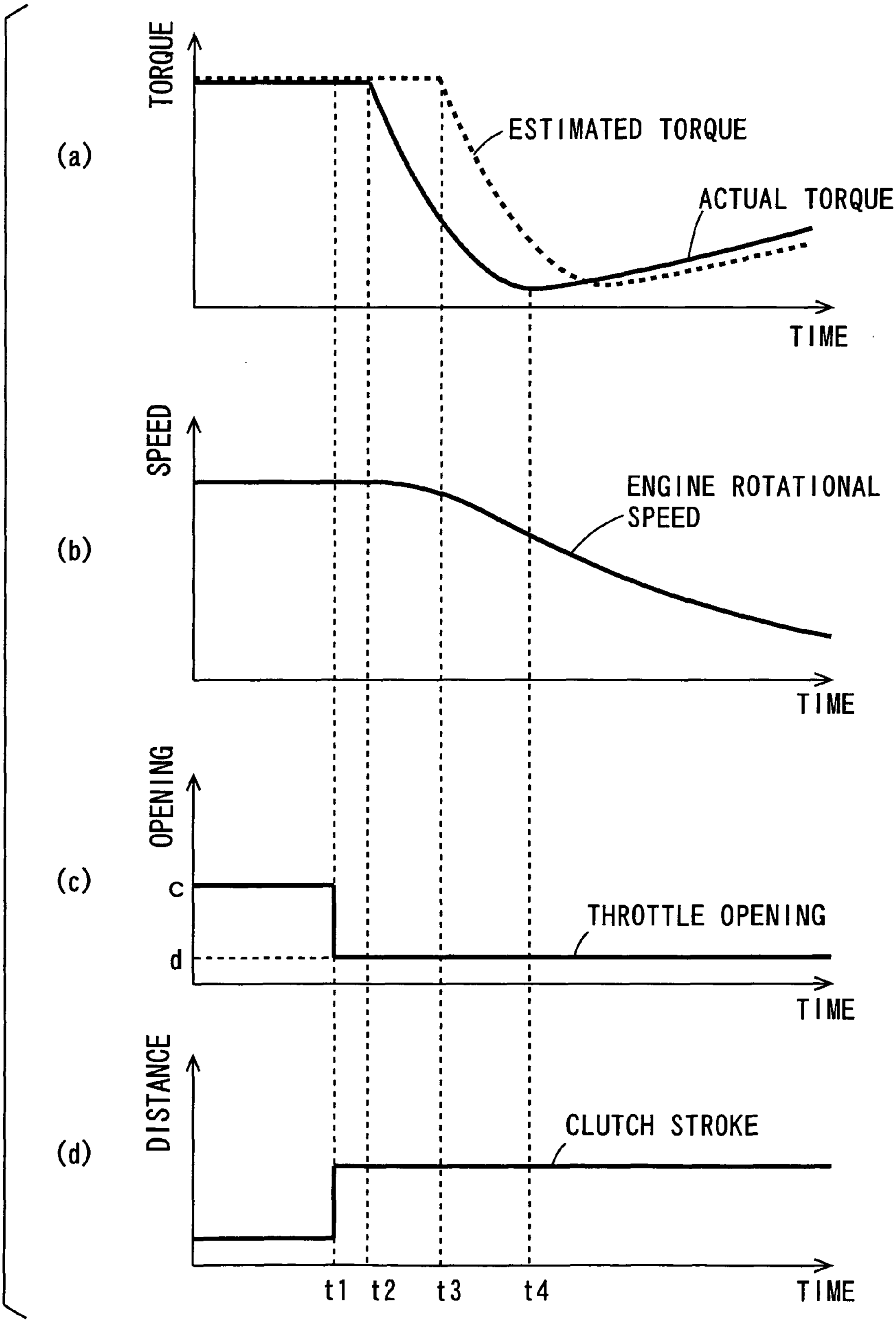
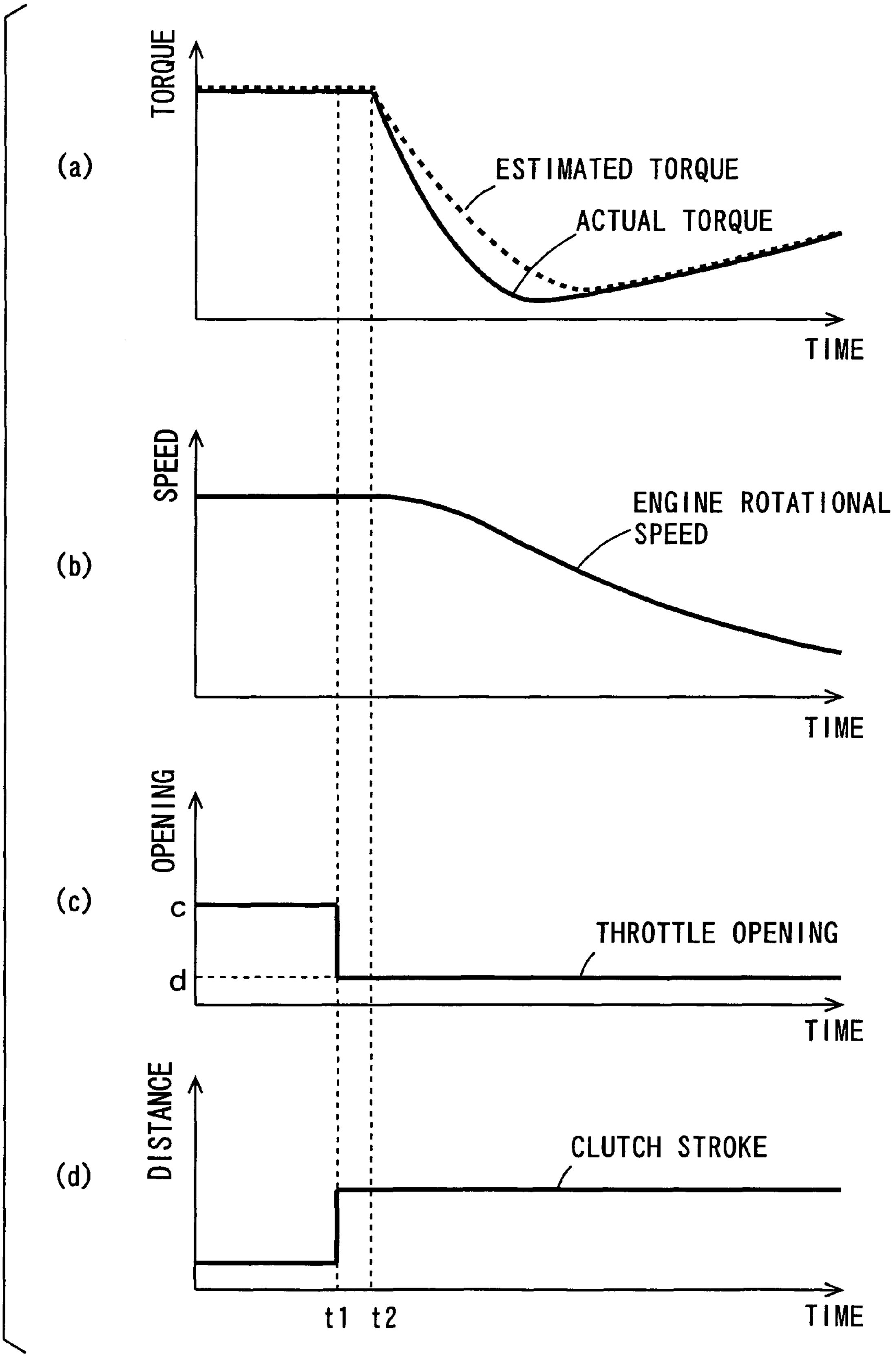

(a)
TORQUE
ESTIMATED TORQUE
ACTUAL TORQUE
TIME
(b)
SPEED
ENGINE ROTATIONAL SPEED
TIME
(c)
OPENING
c
d
THROTTLE OPENING
TIME
(d)
DISTANCE
CLUTCH STROKE
t1
t2
t3
t4
TIME

FIG. 8


(a)
TORQUE
ESTIMATED TORQUE
ACTUAL TORQUE
TIME
(b)
SPEED
ENGINE ROTATIONAL SPEED
TIME
(c)
OPENING
c
d
THROTTLE OPENING
TIME
(d)
DISTANCE
CLUTCH STROKE
t1
t2
TIME

F I G. 9

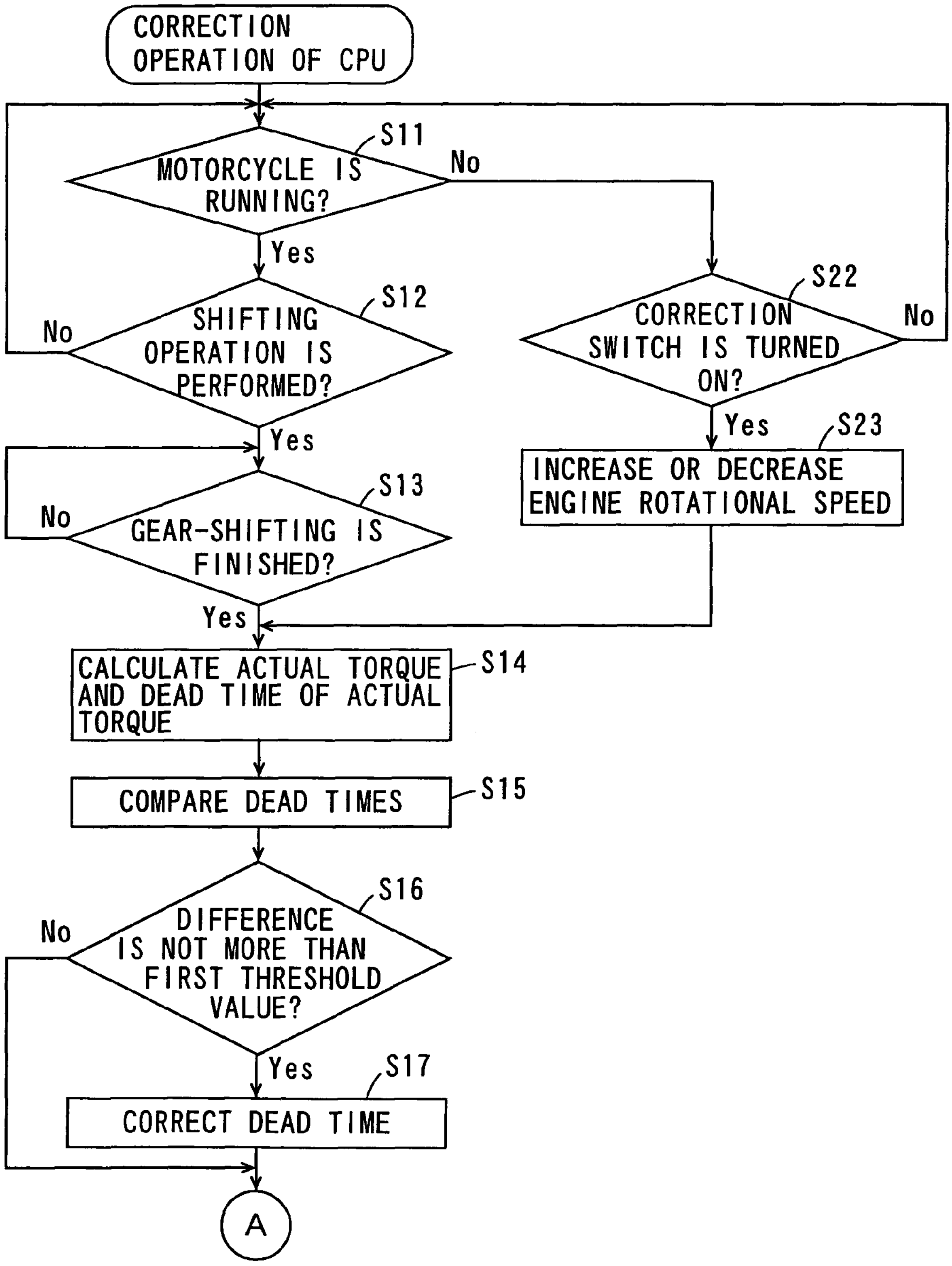
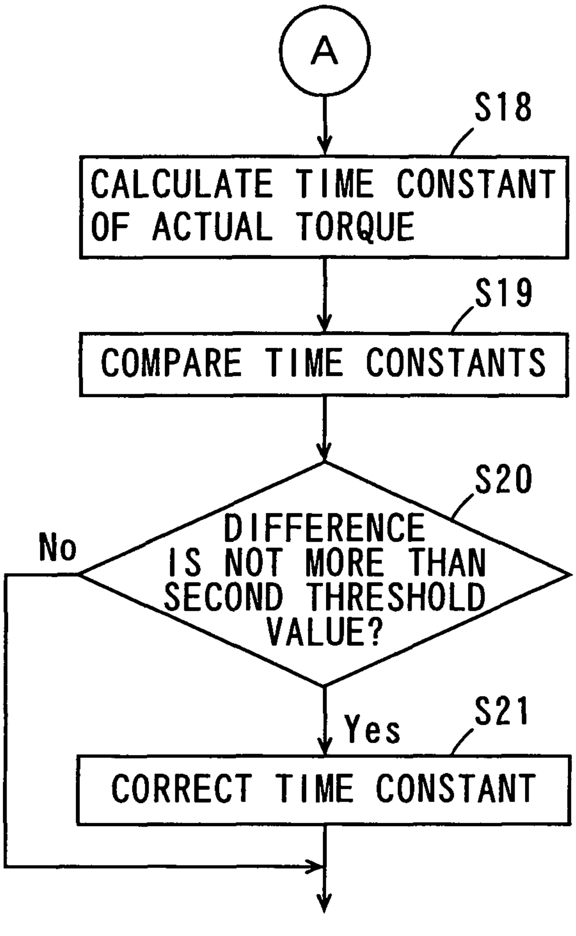

CORRECTION OPERATION OF CPU
S11
MOTORCYCLE IS RUNNING?
No
Yes
S12
SHIFTING OPERATION IS PERFORMED?
No
Yes
S13
GEAR-SHIFTING IS FINISHED?
No
Yes
S22
CORRECTION SWITCH IS TURNED ON?
No
Yes
S23
INCREASE OR DECREASE ENGINE ROTATIONAL SPEED
S14
CALCULATE ACTUAL TORQUE AND DEAD TIME OF ACTUAL TORQUE
S15
COMPARE DEAD TIMES
S16
DIFFERENCE IS NOT MORE THAN FIRST THRESHOLD VALUE?
No
Yes
S17
CORRECT DEAD TIME
A

FIG. 10


A
S18
CALCULATE TIME CONSTANT OF ACTUAL TORQUE
S19
COMPARE TIME CONSTANTS
S20
DIFFERENCE IS NOT MORE THAN SECOND THRESHOLD VALUE?
No
Yes
S21
CORRECT TIME CONSTANT

Europäisches
Patentamt
European
Patent Office
Office européen
des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 09 01 1089

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 7 054 738 B1 (STOTSKY ALEXANDER A [SE]) 30 May 2006 (2006-05-30) * column 3, line 39 - line 52 * * column 4, line 20 - column 5, line 59 * -----	1,9,10	INV. F02D41/14 F02D41/02
A	FR 2 688 546 A (SIEMENS AUTOMOTIVE SA [FR]) 17 September 1993 (1993-09-17) * page 4, line 29 - line 33 * * page 8, line 32 - page 10, line 35 * -----	1,9,10	
A	EP 1 580 416 A (TOYOTA MOTOR CO LTD [JP]) 28 September 2005 (2005-09-28) * paragraphs [0022], [0029] - [0031], [0071] * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)
F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 November 2009	Pileri, Pierluigi

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
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