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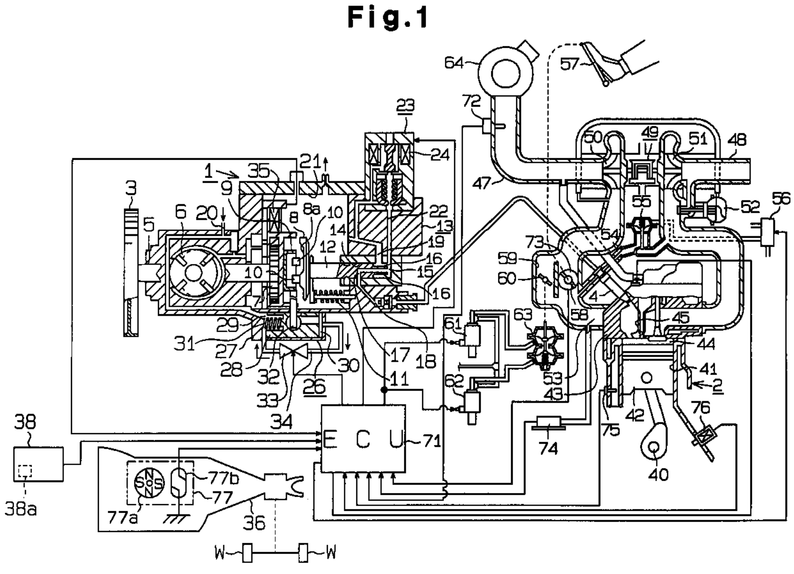
(54) Apparatus for controlling engine torque in a vehicle

(57) An apparatus for controlling the torque of an engine (2) of a vehicle. The vehicle has a drive train for transmitting power of the engine (2) to a driving wheel (W). An electronic control unit (ECU)(71) corrects the fuel injection amount based on the fluctuation of the engine speed to reduce torsional vibration of the drive train. The engine torque is regulated through the correction of the fuel injection amount to reduce the torsional vibration. The ECU (71) does not correct the fuel injection amount when the engine speed is below a predetermined lower limit. The lower limit is different for each shift position of the transmission (36), so that the torsional vibration is accurately reduced in any shift position.

Fig.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an apparatus for controlling engine torque in a vehicle, such as an automobile. More particularly, the present invention relates to an improvement to reduce torsional vibration of a vehicle drive train.

[0002] In general, when a vehicle is rapidly accelerated or decelerated, the engine torque rapidly changes. Rapid changes in the engine torque induce torsional vibration in the drive train. The torsional vibration causes surges in acceleration, simply called surge, which annoys passengers.

[0003] Japanese unexamined patent publication No. 7-324644 discloses an apparatus for reducing torsional vibration. In this apparatus, the following conditions 1-9 must be met before controlling the torsional vibration.

1. The vehicle is a manual transmission vehicle.

2. The engine is not cranking.

3. Engine speed is within a predetermined range.

4. The coolant temperature of the engine is equal to or above a predetermined temperature.

5. The vehicle is moving.

6. A certain time period from when the engine was idling has not yet elapsed.

7. The engine is not idling.

8. The shift position of the transmission is set at a predetermined position.

9. The vehicle is not participating in a motor race.

[0004] If all of the conditions are met, the fluctuation of the engine speed is measured as an indication of the torsional vibration in the drive train of the vehicle. The fuel injection amount is then corrected based on the engine speed fluctuation in accordance with the map shown in Fig. 7. As the fuel injection amount is corrected, the engine torque is adjusted accordingly, so that the torsional vibration is reduced. If the engine speed fluctuation shows a large positive value (right side of Fig. 7), the fuel injection amount is reduced to reduce the engine torque. If the engine speed fluctuation shows a large negative value (left side of Fig. 7), the fuel injection amount is increased to increase the engine torque. By executing engine torque control in this manner, torsional vibration due to torque fluctuation is reduced.

[0005] With regard to the third condition, engine torque control should be performed, for example, in an engine speed range of 1,000 to 4,000 rpm. In a low engine speed range, such as below 1,000 rpm, the drive train of the engine will have vibrations other than torsional vibration. These vibrations influence the measured engine speed fluctuation and cause errors in the correction of the fuel injection amount, which is based on the engine speed fluctuation. This will adversely affect the torsional vibration control. Therefore, the torque control to reduce the torsional vibration is not performed at speeds below 1,000 rpm.

[0006] The critical value of engine speed, below which the vibrations of the drive train adversely affect the torsional vibration control (or the torque control), varies depending on the shift position of the transmission. Therefore, in the prior art apparatus, in order to avoid the adverse affect on the torque control at all shift positions, the lower limit of the engine speed was set based on the critical engine speed while the transmission was in a shift position at which the critical engine speed was maximum. Therefore, at other shift positions, the control of the torsional vibration is not performed even though the engine speed is above the critical engine speed. This results in surge due to torsional vibration.

[0007] Also, the lower limit of the engine speed could be shifted according to running conditions of the vehicle other than the shift position of the transmission, such as engine temperature and engine load.

[0008] Furthermore, in the prior art apparatus, the correction of the fuel injection amount is conducted in accordance with only one map (Fig. 7) during both acceleration and deceleration of the vehicle. However, the present inventors found that, if the same correction amount is used for correcting the fuel injection amount during both acceleration and deceleration, the torsional vibration cannot be adequately controlled.

SUMMARY OF THE INVENTION

[0009] Accordingly, it is an objective of the present invention to provide an apparatus for controlling torque of an engine of a vehicle, capable of adequately reducing the torsional vibration in any vehicle running conditions.

[0010] For achieving the objective of the present invention, an apparatus for controlling torque of an engine of a vehicle, which has a drive train for transmitting power of the engine to a driving wheel, includes a regulating means for regulating the torque of the engine based on an amount of engine speed fluctuation to reduce vibration of the drive train and a disallowing means for disallowing the regulating means to regulate the torque of the engine when the engine speed is below a predetermined reference value. The apparatus further includes an adjusting means for adjusting the reference value based on a running condition of the vehicle.

[0011] The present invention also provides an apparatus for controlling torque of an engine of a vehicle, which has a drive train for transmitting power of the engine to a driving wheel. The apparatus includes a regulating means for regulating the torque of the engine based on an amount of engine speed fluctuation to reduce vibration of the drive train. The regulating means regulates the torque of the engine with a torque correction amount. The torque correction amount during acceleration of the vehicle differs from the torque correction amount during deceleration of the vehicle for a given amount of engine speed fluctuation.

[0012] Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention, together with objectives and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a schematic structural view of the apparatus for controlling torque of a diesel engine according to a first embodiment of the present invention;

Fig. 2 is a diagrammatic cross sectional view of an fuel injection pump of Fig. 1;

Fig. 3 is a block diagram, showing a circuit construction of an electronic control unit (ECU);

Fig. 4 is a flow chart, showing a torque control procedure of the present invention;

Fig. 5 is a table, showing shift positions and corresponding lower limits of the engine speed;

Fig. 6 is a map, showing relationship between the engine speed fluctuation and the fuel injection correction amount of the present invention; and

Fig. 7 is a map, showing relationship between the fluctuation of the engine speed and the fuel injection correction amount of the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] An apparatus for controlling the torque of a diesel engine according to a first embodiment of the present invention will be described with reference to the drawings. As shown in Fig. 1, the diesel engine 2 includes a fuel injection pump 1. The fuel injection pump 1 includes a drive pulley 3 and a drive shaft 5. The drive pulley 3 is connected to a crank shaft 40 of the engine 2 with, for example, a belt. The fuel injection pump 1 is driven when the drive shaft 5 is rotated with the drive pulley 3. As a result, fuel is pumped from the fuel injection pump 1 to fuel injection nozzles 4, which are provided in each cylinder of the diesel engine 2. The fuel is then discharged from the nozzles 4.

[0015] A manual transmission 36 is connected to the diesel engine 2. The manual transmission 36 has shift positions (in this embodiment, the number of the shift positions is five, corresponding to the first to fifth speeds) and shifts the engine speed between the first speed and the fifth speed in response to manual shift operation of a driver. In Fig. 1, although the manual transmission 36 is shown to be separated from the engine 2 for convenience, the manual transmission 36 is connected to the crank shaft 40. The rotation of the crank shaft 40 is transmitted to driving wheels W of the vehicle via the transmission 36. That is, the power of the engine 2 is transmitted to the driving wheels W via a drive train, which includes the crank shaft 40 and the transmission 36.

[0016] The diesel engine 2 has cylinder bores 41 and pistons 42, which are accommodated in the cylinder bores 41. The upper end of each cylinder bore 41 is closed with a cylinder head 43. A main combustion chamber 44 is defined in each cylinder bore 41 between the cylinder head 43 and the piston 42. The cylinder head 43 has a subsidiary combustion chamber 45, which is communicated with the main combustion chamber 44. The fuel injection nozzle 4 injects fuel into the subsidiary combustion chamber 45.

[0017] The diesel engine 2 further includes an intake passage 47 and an exhaust passage 48. A compressor 50 and a turbine 51 of a turbocharger 49 are respectively arranged in the intake passage 47 and the exhaust passage 48. A waste gate valve 52, which regulates boost pressure, is further arranged in the exhaust passage 48. As is known, the turbine 51 of the turbocharger 49 is rotated by the exhaust gas to rotate the compressor 50, which is coaxially arranged with the turbine 51. A large amount of air is supplied to the main combustion chamber 44 from the intake passage 47 through an intake port 53 to promote combustion of fuel for increasing power of the diesel engine 2.

[0018] The diesel engine 2 further includes an exhaust gas recirculation system (EGR). The EGR includes an EGR passage 54 and a diaphragm type EGR valve 55, which is provided in the EGR passage 54. Some of the exhaust gas in the exhaust passage 48 is returned to the intake passage 47 through the EGR passage 54. An electric vacuum regulating valve (EVRV) 56 regulates pressure that is applied to the EGR valve 55 to regulate the opening of the EGR valve 55. With this, the amount of exhaust gas, which is conducted from the exhaust passage 48 to the intake passage 47 through the EGR passage 54, is regulated.

[0019] A throttle valve 58, which is operated based on the depression amount of a gas pedal 57, is arranged in the intake passage 47. A bypass passage 59, which bypasses the throttle valve 58, is connected to the intake passage 47. A flow-restricting valve 60 is arranged in the bypass passage 59. The flow-restricting valve 60 is driven by an actuator 63, which includes two diaphragm chambers. The actuator 63 is controlled by two vacuum switching valves (VSV) 61 and 62. The flow-restricting valve 60 is controlled based on the current running conditions of the engine 2. For example, the flow-restricting valve 60 is half opened to reduce noise and vibration during idling of the engine, is fully opened during normal running of the vehicle, and is fully closed when the engine 2 is shut down.

[0020] The diesel engine 2 further includes a starter 38, which starts the engine 2 by rotating an electric motor, which is powered by a battery.

[0021] The construction of the fuel injection pump 1 will now be described with reference to Fig. 2. The drive shaft 5, which is connected to the drive pulley 3, has a disc shaped pulser 7 at its inner end. The pulser 7 has teeth arranged in segments, which are equally spaced apart. The number of segments is equal to the number of cylinders in the engine. Each segment has a number of equally spaced teeth. A vane feed pump 6 (rotated 90 degrees to show details in Fig. 2) is arranged at the middle of the drive shaft 5. A roller ring 9, which is rotatable relative to the drive shaft 5, is supported on the inner end of the drive shaft 5. The roller ring 9 can be rotated or held stationary by a timing device 26 (rotated 90 degrees to show details in Fig. 2) while the drive shaft 5 is rotated. The details and functions of the timing device 26 will be described later. The roller ring 9 has cam rollers 10, which are arranged in the circumferential direction of the roller ring 9.

[0022] The fuel injection pump 1 includes a plunger 12, which is coaxial with the drive shaft 5. A cam plate 8 is attached to the end of the plunger 12, which is opposed to the roller ring 9. The cam plate 8 has a cam face 8a, which is opposed to the roller ring 9. The cam face 8a has lobes. The number of lobes is equal to the number of cylinders of the engine 2. A coupling (not shown) is accommodated in the roller ring 9. The coupling couples the drive shaft 5 and the cam plate 8 to rotate the cam plate 8 integrally with the drive shaft 5. The coupling allows axial movement of the cam plate 8 and the plunger 12. The cam plate 8 is urged against the cam rollers 10 by a spring 11 to continuously engage the cam face 8a with the cam rollers 10.

[0023] When the drive shaft 5 is rotated, the cam plate 8 is integrally rotated with the drive shaft 5 via the coupling. During rotation of the cam plate 8, the cam plate 8 is also reciprocated in axial direction through engagement of the cam plate 8 and the cam rollers 10. The number of reciprocations of the cam plate 8 per rotation of the cam plate 8 is equal to the number of cylinders of the engine 2. As the cam plate 8 is rotated and reciprocated, the plunger 12 is integrally rotated and reciprocated with the cam plate 8. More specifically, as the lobes of the cam face 8a are rotated and are engaged with corresponding cam rollers 10, the plunger 12 is urged to move in the rightward direction of Fig. 2. Furthermore, as the lobes of the cam face 8a are further rotated to move away from the cam rollers 10, the plunger 12 is urged to move in leftward direction of Fig. 2 by the spring 11.

[0024] The plunger 12 is received in a cylinder 14, which is defined in a pump housing 13. A pressure chamber 15 is defined between a distal end face of the plunger 12 and the inner wall of the cylinder 14. Intake grooves 16 are defined around the periphery of the distal end of the plunger 12. The number of intake grooves 16 is equal to the number of cylinders of the engine 2. Also, a distribution port 17 is formed on the periphery of the plunger 12. An intake port 19 is formed in the pump housing 13. The intake port 19 is radially aligned with each of the intake grooves 16 at various rotational positions of the plunger 12. Furthermore, distribution passages 18, which intermittently communicate with the distribution port 17, are defined in the pump housing 13.

[0025] As the feed pump 6 is driven by rotation of the drive shaft 5, fuel is supplied in the fuel chamber 21 from a fuel tank (not shown) through a supply port 20. As the plunger 12 is moved in the leftward direction of Fig. 2 (i.e., as the plunger 12 performs a suction stroke) through the rotation of the drive shaft 5, the pressure chamber 15 is depressurized. When one of the intake grooves 16 is aligned with the intake port 19, fuel is drawn into the pressure chamber 15 from the fuel chamber 21. As the plunger 12 is moved in the rightward direction of Fig. 2 (i.e., as the plunger 12 performs a compression stroke), the pressure chamber 15 is pressurized, so that fuel in the pressure chamber 15 is forced into the fuel injection nozzles 4 (Fig. 1) through the respective distribution passage 18.

[0026] The pressure chamber 15 is communicated with the fuel chamber 21 via a spill passage 22. An electromagnetic spill valve 23 is provided in the spill passage 22. The spill valve 23 is a normally open valve, which has a solenoid 24. That is, the spill valve 23 is held open when no electric current is supplied to the solenoid 24. When the spill valve 23 is open, fuel in the pressure chamber 15 escapes into the fuel chamber 21 through the spill passage 22. When electric current is supplied to the solenoid 24, the spill valve 23 closes the spill passage 22 to prevent the escape of fuel from the pressure chamber 15 into the fuel chamber 21.

[0027] When the spill valve 23 opens the spill passage 22 during the compression stroke of the plunger 12, the pressure chamber 15 is depressurized, and fuel injection from the fuel injection nozzle 4 is terminated. Therefore, the spill valve 23 regulates the cut-off timing of fuel injection from the fuel injection nozzle 4. That is, the spill valve 23 regulates the amount of fuel injected from the fuel injection nozzle 4.

[0028] The timing device 26 (rotated 90 degrees in Fig. 2) is provided at the bottom of the pump housing 13. The timing device 26 controls the injection timing of fuel from the fuel injection nozzle 4. The timing device 26 changes the rotational position of the roller ring 9 about the axis of the drive shaft 5. In accordance with positional changes of the roller ring 9, the timing at which the lobes on the cam face 8a engage the cam rollers 10 is changed. In another words, the timing at which the compression stroke of the plunger 12 is initiated is changed.

[0029] The timing device 26 is driven by hydraulic pressure and includes a housing 27 and a piston 28, which is accommodated in the housing 27. In the housing 27, a low pressure chamber 29 is defined at one side of the piston 28, and a pressurizing chamber 30 is defined at the other side of the piston 28. A spring 31, which is positioned in the low pressure chamber 29, urges the piston 28 against the pressurizing chamber 30. The piston 28 is connected to the roller ring 9 via a slide pin 32. In accordance with movement of the piston 28, the roller ring 9 is pivoted about its axis by the slide pin 32.

[0030] Fuel, which is pressurized by the feed pump 6, is supplied to the pressurizing chamber 30. The axial position of the piston 28 is changed in accordance with the balance between fuel pressure in the pressurizing chamber 30 and the urging force of the spring 31. The rotational position of the roller ring 9 is changed in accordance with the axial position of the piston 28. In another words, the timing at which the plunger 12 initiates reciprocation is determined based on the position of the piston 28.

[0031] The pressurizing chamber 30 and the low pressure chamber 29 are connected by a communication passage 34. A timing control valve (TCV) 33, which is an electromagnetic valve, is arranged in the communication passage 34. Opening and closing of the TCV 33 are controlled by a duty signal. The TCV 33 regulates the flow rate of fuel in the communication passage 34 to regulate the fuel pressure in the pressuring chamber 30. The position of the piston 28 changes in accordance with the changes of fuel pressure in the pressurizing chamber 30, so that the injection timing of fuel from respective fuel injection nozzle 4 is changed.

[0032] An engine speed sensor 35, which includes an electromagnetic pickup coil, is arranged to face the circumferential surface of the pulser 7. The engine speed sensor 35 outputs a pulse signal as each ridge of the pulser 7 passes the engine speed sensor 35. The pulse signal is output when the crank shaft 40 of the engine 2 is rotated for a predetermined rotational angle. As a result, the engine speed NE can be measured based on the time interval between subsequent pulse signals. The engine speed sensor 35 is integrally pivoted with the roller ring 9. Therefore, the phase of the pulse signal, which is output from the sensor 35, has a constant relationship with the reciprocal phase of the plunger 12, even though the roller ring 9 is pivoted by the timing device 26.

[0033] The engine 2 has sensors other than the engine speed sensor 35 to measure running conditions of the engine 2. More specifically, as shown in Fig. 1, an intake air temperature sensor 72, which measures intake air temperature THA, is arranged near an air cleaner 64, which is positioned at an air inlet of the intake passage 47. A gas pedal sensor 73, which measures the degree of depression of the throttle valve 58 as the depression amount ACCP of the gas pedal 67, is arranged near the throttle valve 58. The depression amount ACCP indicates the amount of engine load. An intake air pressure sensor 74, which measures pressure PM of the intake air after pressurization by the turbocharger 49, is arranged near the intake port 53. Coolant temperature sensor 75, which measures circulating coolant temperature THW, is arranged in a water jacket of the engine 2. A crank angle sensor 76, which measures a reference rotational position of the crank shaft 40, is arranged near the crank shaft 40. A vehicle speed sensor 77 is arranged in the manual transmission 36. The vehicle speed sensor 77 includes a magnet 77a, which is rotated by a gear of the transmission 36, and a reed switch 77b, which is switched between ON and OFF states by the magnet 77a. The vehicle speed sensor 77 measures vehicle speed SPD based on the state (ON/OFF) of the reed switch 77b. A starter switch 38a, which detects activation of the starter 38, is arranged in the starter 38.

[0034] The electromagnetic spill valve 23, the TCV 33, the EVRV 56, the VSV 61, 62, the sensors 35, 72-77 and the starter 38 are connected to an electronic control unit (ECU) 71. The ECU 71 adequately controls the electromagnetic spill valve 23, the TCV 33, EVRV 56 and VSV 61, 62 based on signals, which are transmitted from the sensors 35,72-77 and the starter switch 38a.

[0035] Construction of the ECU 71 will now be described with reference to Fig. 3. The ECU 71 includes a central processing unit (CPU) 81, a read only memory (ROM) 82, which stores various control programs and functional data, a random access memory (RAM) 83, which temporarily stores data, such as, computed data of the CPU 81 and the engine speed NE, and a backup RAM 84, which is a nonvolatile RAM that is backed up by a battery. The ECU 71 is constructed as a logic circuit, in which respective components 81-84 are connected to the input port 85 and the output port 86 via a bus 87.

[0036] The intake air temperature sensor 72, the gas pedal sensor 73, the intake air pressure sensor 74 and the coolant temperature sensor 75 are connected to the input port 85 via the buffers 88, 89, 90, 91, a multiplexer 93 and an A/D converter 94. Furthermore, the engine speed sensor 35, the starter switch 38a, the crank angle sensor 76 and the vehicle speed sensor 77 are connected to the input port 85 via a waveform shaping circuit 95. The CPU 81 receives signals transmitted from the sensors 35, 72-77 and the starter switch 38a via the input port 85. The electromagnetic spill valve 23, the TCV 33, EVRV 56 and VSV 61, 62 are connected to the output port 86 via drive circuits 96, 97, 99, 100, 101.

[0037] The fuel injection amount control, which is conducted by the ECU 71, will now be described with reference to Figs. 4 to 6.

[0038] Fig. 4 is a flow chart, showing "a correction amount computing routine" for computing the correction amount QA (or the torque correction amount), which is used for correcting the fuel injection amount. This routine is conducted along with a fuel injection amount computing process, which is conducted at predetermined crank angles. In the fuel injection amount computing process, the basic fuel injection amount is computed based on the running conditions of the engine 2. The corrected fuel injection amount is obtained by adding the correction amount QA, which is computed in the routine of the Fig. 4, to the basic fuel injection amount. If the corrected fuel injection amount is smaller than a maximum fuel injection amount, the corrected fuel injection amount is used as a final fuel injection amount. Fuel injection is conducted at the fuel injection nozzle 4 in accordance with the final injection amount. The maximum fuel injection amount is the maximum allowable amount of fuel to be injected in each combustion chamber 44. In another words, the maximum fuel injection amount is computed as a maximum limit for preventing a rapid increase in the amount of smoke discharged from the combustion chamber 44 and for preventing excess engine torque. Therefore, if the corrected fuel injection amount is greater than the maximum fuel injection amount, the maximum fuel injection amount is used as the final fuel injection amount.

[0039] The torque of the engine 2 is adjusted by correcting the fuel injection amount with the correction amount QA, which is computed through the routine of Fig. 4. As a result, torsional vibration in the drive train of the vehicle and surge, which is a result of the torsional vibration, are reduced. Therefore, the flow chart of Fig. 4 shows part of the torque control procedure for reducing the torsional vibration.

[0040] When the procedure enters the routine of Fig. 4, the ECU 71 reads the current engine speed NE, the gas pedal depression amount ACCP, the fluctuation amount DLNE of the engine speed and the shift position SFP of the transmission 36 in step 101. The fluctuation amount DLNE of the engine speed indicates the degree of torsional vibration, and is obtained by subtracting the previous value of the engine speed NE, which is obtained from the previous cycle of the routine, from the current engine speed NE. The shift position SFP is obtained from a map (not shown) based on the ratio of the engine speed NE relative to the vehicle speed SPD.

[0041] In step 102, the ECU 71 then determines the lower limit NQ of the engine speed for the current shift position SFP in accordance with a table, such as the table of Fig. 5, and stores the lower limit NQ in the RAM 83. The lower limit NQ is used to determine whether torque control for reducing torsional vibration should be performed for the current shift position SFP. As shown in Fig. 5, the higher the shift position is (i.e., the smaller the gear ratio is), the greater the lower limit NQ will be. At the first shift position SFP, the lower limit NQ is set to 700 rpm (or 680 rpm).

[0042] In the next step 103, the ECU 71 sets an execution flag F, which indicates whether the torque control for reducing the torsional vibration is required. The execution flag F will be set to one when the torque control is required. Otherwise, the execution flag F will be set to zero. In the present embodiment, if all of the following preconditions 1-6 are met, the execution flag F is set to one to indicate the need for torque control.

1. The vehicle is a manual transmission vehicle, and the shift position SFP of the transmission 36 is set at a predetermined position (for example, any one of the shift positions corresponding to the first to fifth speeds).

2. The engine 2 is not cranking.

3. The engine speed NE is below a predetermined speed (for example, 4,000 rpm).

4. Coolant temperature THW of the engine 2 is equal to or above a predetermined temperature (for example, -20 degrees Celsius).

5. The fluctuation amount DLNE of the engine speed is below a predetermined speed difference (for example, 350 rpm).

6. The vehicle is moving (i.e., the vehicle speed SPD is not zero).

[0043] With regard to precondition 2, when the starter switch 38a is turned on, and the engine speed NE is equal to or below a predetermined speed, the ECU 71 interprets that the engine 2 is cranking. Precondition 5 is provided for eliminating any phenomenon that is not induced by the torsional vibration. That is, when the fluctuation amount DLNE of the engine speed is equal to or greater than 350 rpm, the ECU 71 interprets that the engine speed fluctuation is caused by the operator missing the proper shift position or by a sudden shift change. Thus, the execution flag F is set to zero to prevent execution of torque control.

[0044] In step 104, the ECU 71 determines whether the execution flag F is one. If the execution flag F is not one, the ECU 71 decides that torque control should not be conducted, and terminates the routine without computing the correction amount QA. Therefore, in the fuel injection amount computing process, which is conducted separately, the basic fuel injection amount is not corrected, and the final fuel injection amount is determined based on the basic fuel injection amount.

[0045] If the execution flag F is one in step 104, the ECU 71 decides that the torque should be controlled, and proceeds to step 105. In step 105, the ECU 71 determines whether the engine speed NE is equal to or greater than the lower limit NQ, which is set based on the shift position SFP. If the engine speed NE is below the lower limit NQ, the ECU 71 decides that the torque control should not be conducted, and terminates the routine without computing the correction amount QA.

[0046] If the engine speed NE is equal to or greater than the lower limit NQ in step 105, the ECU 71 proceeds to step 106. In step 106, the ECU 71 determines whether the gas pedal depression amount ACCP is greater than zero, or if the gas pedal 57 is depressed. This will determine whether the vehicle is in accelerating or decelerating. That is, if the gas pedal depression amount ACCP is greater than zero, the ECU 71 interprets that the vehicle is accelerating. If the gas pedal depression amount ACCP is zero, the ECU 71 interprets that the vehicle is decelerating.

[0047] If the gas pedal depression amount ACCP is greater than zero, the ECU 71 decides that the vehicle is accelerating, and proceeds to step 107. In step 107, the ECU 71 selects the acceleration map M1, which is used during acceleration and is indicated with a solid line in Fig. 6, and proceeds to step 109. In step 109, the ECU 71 computes the correction amount QA in accordance with the acceleration map M1 and then terminates the routine.

[0048] On the other hand, if the gas pedal depression amount ACCP is zero in step 106, the ECU 71 interprets that the vehicle is decelerating, and proceeds to step 108. In step 108, the ECU 71 selects the deceleration map M2, which is used during deceleration and is indicated with a broken line in Fig. 6, and proceeds to step 109. In step 109, the ECU 71 computes the correction amount QA in accordance with the deceleration map M2 based on the fluctuation amount DLNE of the engine speed and terminates the routine.

[0049] As shown in Fig. 6, the deceleration map M2 shows a greater correction amount QA for corresponding amount of engine speed fluctuation DLNE in comparison with the acceleration map M1.

[0050] By correcting the fuel injection amount with the correction amount QA, the torque of the engine 2 is appropriately adjusted, so the torsional vibration in the drive train of the vehicle is reduced.

[0051] As described above, vibrations of the drive train, which occurs in the low engine speed range, cause errors in computing the correction amount, which is obtained from the fluctuation amount DLNE of the engine speed. This will adversely affect the control of the torque for reducing the torsional vibration. Furthermore, the critical value of the engine speed NE, below which the vibration of the drive train adversely affects the torque control, is changed based on the shift position SFP of the transmission 36. More particularly, the higher the shift position is (i.e., the smaller the gear ratio is), the greater the critical value of the engine speed NE will be.

[0052] In the present embodiment, the lower limit NQ of the engine speed is changed based on the shift position SFP to determine if torque control should be performed (see Fig. 5). If the engine speed NE is equal to or greater than the lower limit NQ, torque control is allowed. If the engine speed is below the lower limit NQ, torque control is disallowed. The lower limit NQ is determined in consideration of the effects of drive train vibration in the respective shift positions SFP. The higher the shift position SFP is (i.e., the smaller the gear ratio is), the greater the lower limit NQ will be. That is, as shown in Fig. 5, the lower limits NQ are the lower limits of the engine speeds at which torsional vibration control can be accurately conducted at the corresponding shift positions SFP. Therefore, the appropriate lower limit NQ is selected in accordance with the current shift position SFP, so that accurate torsional vibration control is conducted in all shift positions SFP.

[0053] In the prior art, there is just one constant lower limit of the engine speeds at which the execution of the torque control is allowed. Therefore, the lower limit must be initially determined at the shift position that has the smallest gear ratio, to control the torque accurately in any shift position. For example, the lower limit may have been set to 1,000 rpm, which corresponds to the lower limit of fifth shift position in Fig. 5. However, at the second shift position, the lower limit of the engine speed is 700 rpm. Therefore, in the second shift position, if the engine speed is in a range of 700 to 1,000 rpm, torque control is disallowed, even though torque control can be accurately conducted. Therefore, the apparatus and method of the illustrated embodiment overcome the drawbacks of the prior art.

[0054] Furthermore, as shown in Fig. 6, correction of the fuel injection amount during acceleration of the vehicle and correction of the fuel injection amount during deceleration of the vehicle are respectively conducted in accordance with different maps M1 and M2. As a result, accurate correction of the fuel injection amount is performed during both acceleration and deceleration of the vehicle, which respectively require different fuel injection correction amounts. Therefore, torsional vibration is accurately reduced.

[0055] The torque is controlled by regulating the fuel injection amount, so the torque is controlled accurately and reliably.

[0056] The fluctuation amount DLNE of the engine speed correlates with the degree of the torsional vibration. Therefore, the degree of torsional vibration can be adequately derived based on the fluctuation amount DLNE. That is, torsional vibration can be adequately reduced by regulating the fuel injection amount based on the fluctuation amount DLNE of the engine speed.

[0057] The present invention is not limited to the illustrated embodiment and can be modified as follows.

[0058] The lower limits NQ of the engine speed corresponding to shift positions SFP are not limited to the values of Fig. 5. Values other than those of Fig. 5 can be used as the lower limits NQ if the values of the lower limit NQ increase as the gear ratio decrease (i.e., as higher shift position is selected). That is, values other than those of Fig. 5 can be used if the lower limit NQ is properly modified based on characteristics of the engine 2, characteristics of the transmission 36 and characteristics of vehicles that include the engine 2 and the transmission 36.

[0059] Likewise, the maps M1 and M2 can be modified in accordance with characteristics of the engine 2, characteristics of the transmission 36 and characteristics of vehicles that include the engine 2 and the transmission 36.

[0060] In the embodiment of Figs. 1 to 6, the shift position SFP is interpreted based on the ratio of the engine speed NE relative to the vehicle speed SPD. Alternatively, the shift position can be interpreted based on a signal of a sensor arranged in the transmission 36 to detect the shift position.

[0061] In the embodiment of Figs. 1 to 6, whether the vehicle is accelerating or decelerating is determined based on the gas pedal depression amount ACCP, which is measured with the gas pedal sensor 73. Alternatively, whether the vehicle is accelerating or decelerating can be determined based on a signal of a switch, which detects whether the gas pedal 57 is being operated.

[0062] In the embodiment of Figs. 1 to 6, two processes, namely, the process to determine the lower limit NQ based on the shift position SFP and the process to compute the correction amount QA, which is appropriately obtained for both acceleration and deceleration of the vehicle, are conducted. Alternatively, only one of these processes can be conducted. Even with this variation, the torsional vibration is more appropriately reduced based on the running conditions of the vehicle than in the prior art.

[0063] The lower limit of the engine speeds at which the reduction control of the torsional vibration can be adequately conducted, could be influenced by running conditions other than the shift position, such as the circulating coolant temperature of the engine 2 or the load of the engine 2. Therefore, the lower limit NQ of the engine speed for allowing execution of the torque control can be changed based on the shift position SFP and/or other running conditions.

[0064] In the preferred embodiment, six conditions 1-6 must be met before executing torque control. However, types and the number of the conditions or values specified in the conditions can be changed.

[0065] The number of shift positions of the transmission 36 is not limited to five. Furthermore, the present invention can be applied to automatic transmission vehicles.

[0066] In the present embodiment, the torque is controlled by regulating the fuel injection amount. Alternatively, the torque can be controlled by regulating the fuel injection timing.

[0067] The present invention is not limited to diesel engines 2 and can be applied to gasoline engines. In the case of gasoline engines, the torque can be controlled by regulating the ignition timing, the air-fuel ratio or the intake air amount instead of the fuel injection amount and the fuel injection timing.

[0068] Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

[0069] An apparatus for controlling the torque of an engine (2) of a vehicle. The vehicle has a drive train for transmitting power of the engine (2) to a driving wheel (W). An electronic control unit (ECU)(71) corrects the fuel injection amount based on the fluctuation of the engine speed to reduce torsional vibration of the drive train. The engine torque is regulated through the correction of the fuel injection amount to reduce the torsional vibration. The ECU (71) does not correct the fuel injection amount when the engine speed is below a predetermined lower limit. The lower limit is different for each shift position of the transmission (36), so that the torsional vibration is accurately reduced in any shift position.

Claims

1. An apparatus for controlling torque of an engine (2) of a vehicle, which has a drive train for transmitting power of the engine (2) to a driving wheel (W), the apparatus comprising:

   a regulating means (1, 71) for regulating the torque of the engine (2) based on an amount of engine speed fluctuation to reduce vibration of the drive train; and
   a disallowing means (71) for disallowing the regulating means (1, 71) to regulate the torque of the engine (2) when the engine speed is below a predetermined reference value, the apparatus being **characterized by**:
   an adjusting means (71) for adjusting the reference value based on a running condition of the vehicle.

2. An apparatus according to claim 1, **characterized in that** the vehicle comprises a transmission (36), which is connected to the engine (2), wherein the transmission (36) has a plurality of shift positions for changing the gear ratio of the transmission (36), and wherein the adjusting means (71) adjusts the reference value based on the shift position of the

transmission (36).

3. An apparatus according to claim 2, **characterized in that** the adjusting means (71) increases the reference value as the gear ratio of the transmission (36) is reduced.

4. An apparatus according to claim 2 or 3, **characterized by** an estimating means (71) for estimating the current shift position based on the ratio of the engine speed to the speed of the vehicle.

5. An apparatus according to any one of claims 1 to 4, **characterized in that** the regulating means (1, 71) regulates the torque of the engine (2) with a torque correction amount, wherein the torque correction amount during the acceleration of the vehicle differs from the torque correction amount during deceleration of the vehicle for a given amount of engine speed fluctuation.

6. An apparatus according to claim 5, **characterized in that** the absolute value of the torque correction amount during the deceleration of the vehicle is greater than the absolute value of the torque correction amount during the acceleration of the vehicle for a given amount of engine speed fluctuation.

7. An apparatus according to any one of claims 1 to 6, **characterized in that** the engine (2) comprises a combustion chamber (44) and a fuel injection means (4) for injecting fuel into the combustion chamber (44), wherein the regulating means (1, 71) regulates the amount of fuel injected from the fuel injection means (4) into the combustion chamber (44) to regulate the torque of the engine (2).

8. An apparatus according to any one of claims 1 to 7, **characterized by**:

   a detecting means (35) for detecting the engine speed; and
   a computing means (71) for computing the change in the detected engine speed over a predetermined time period as an indication of the degree of torsional vibration in the drive train.

9. An apparatus for controlling torque of an engine (2) of a vehicle, which has a drive train for transmitting power of the engine (2) to a driving wheel (W), the apparatus comprising a regulating means (1, 71) for regulating the torque of the engine (2) based on an amount of engine speed fluctuation to reduce vibration of the drive train, the apparatus being **characterized in that**:

   the regulating means (1, 71) regulates the torque of the engine (2) with a torque correction amount, wherein the torque correction amount during acceleration of the vehicle differs from the torque correction amount during deceleration of the vehicle for a given amount of engine speed fluctuation.

10. An apparatus according to claim 9, **characterized in that** the absolute value of the torque correction amount during the deceleration of the vehicle is greater than the absolute value of the torque correction amount during the acceleration of the vehicle for a given amount of engine speed fluctuation.

Fig.1

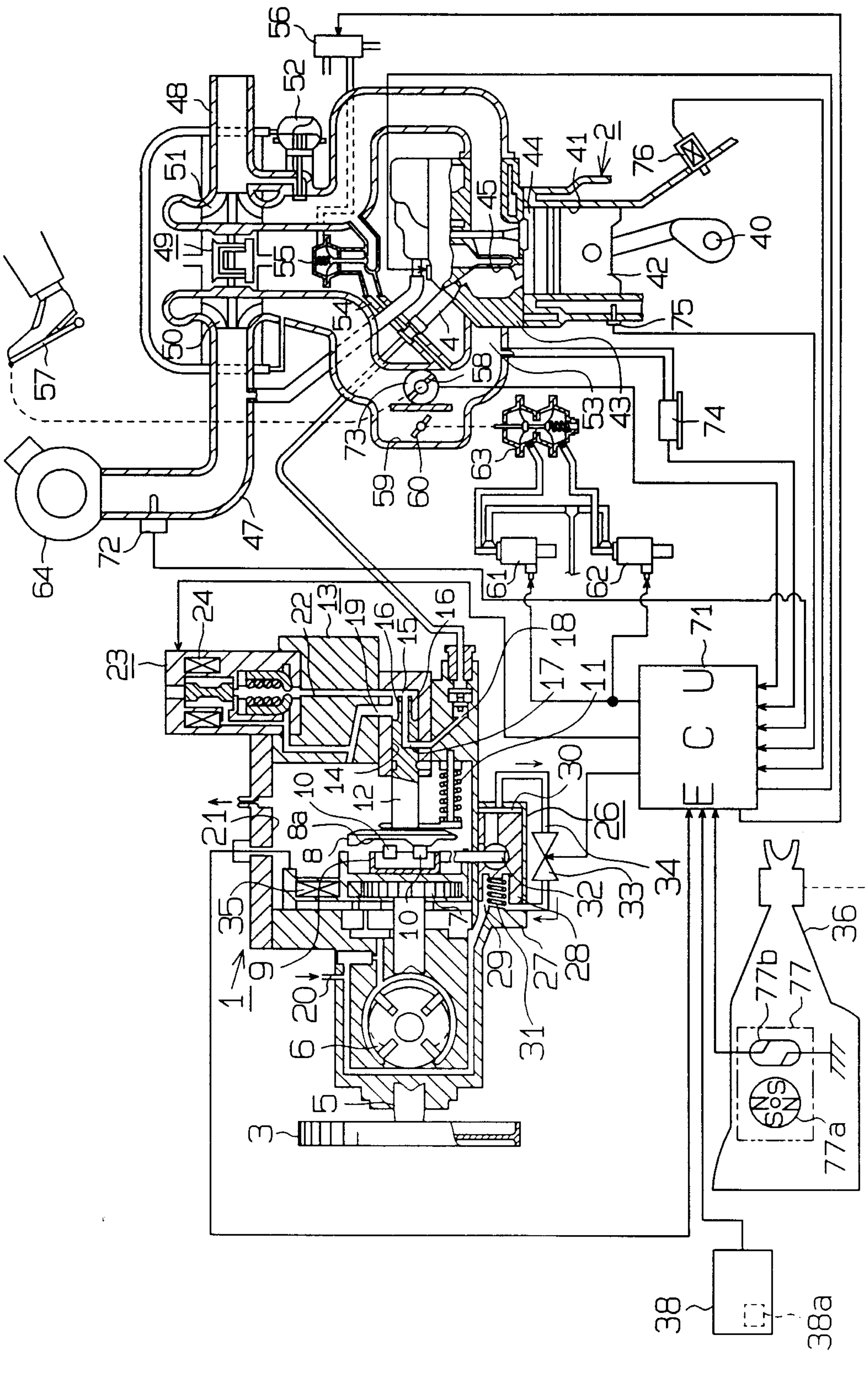

Fig.2

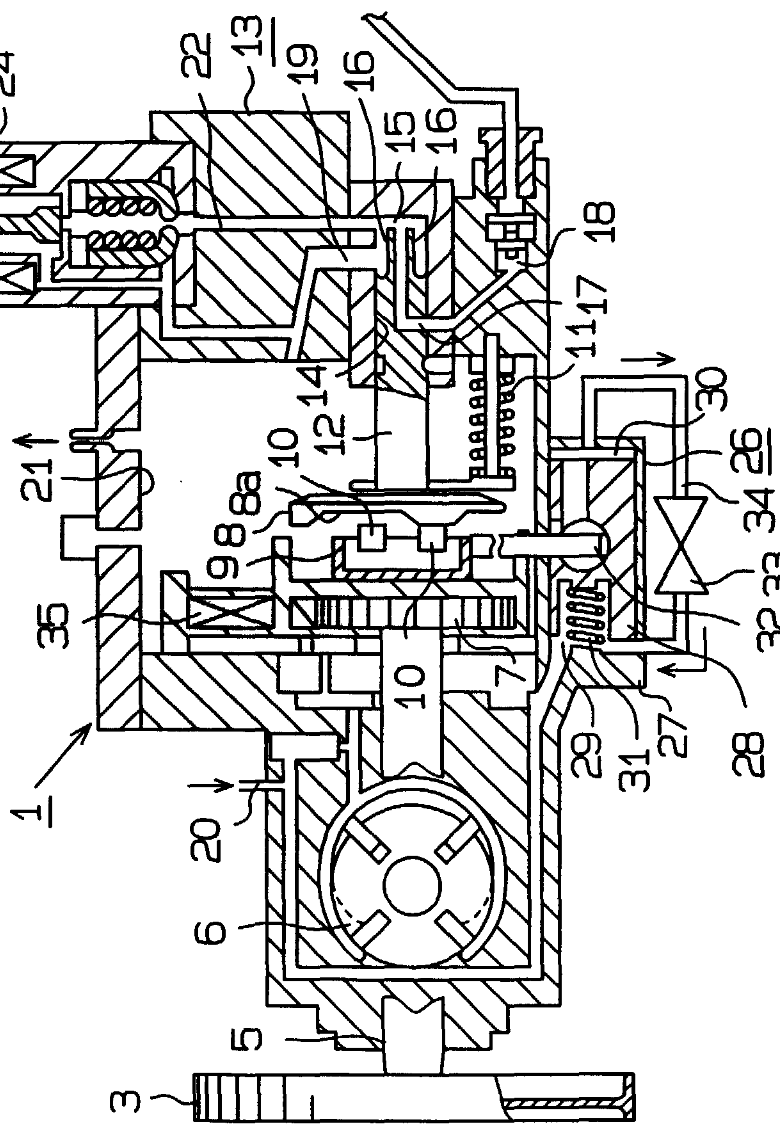
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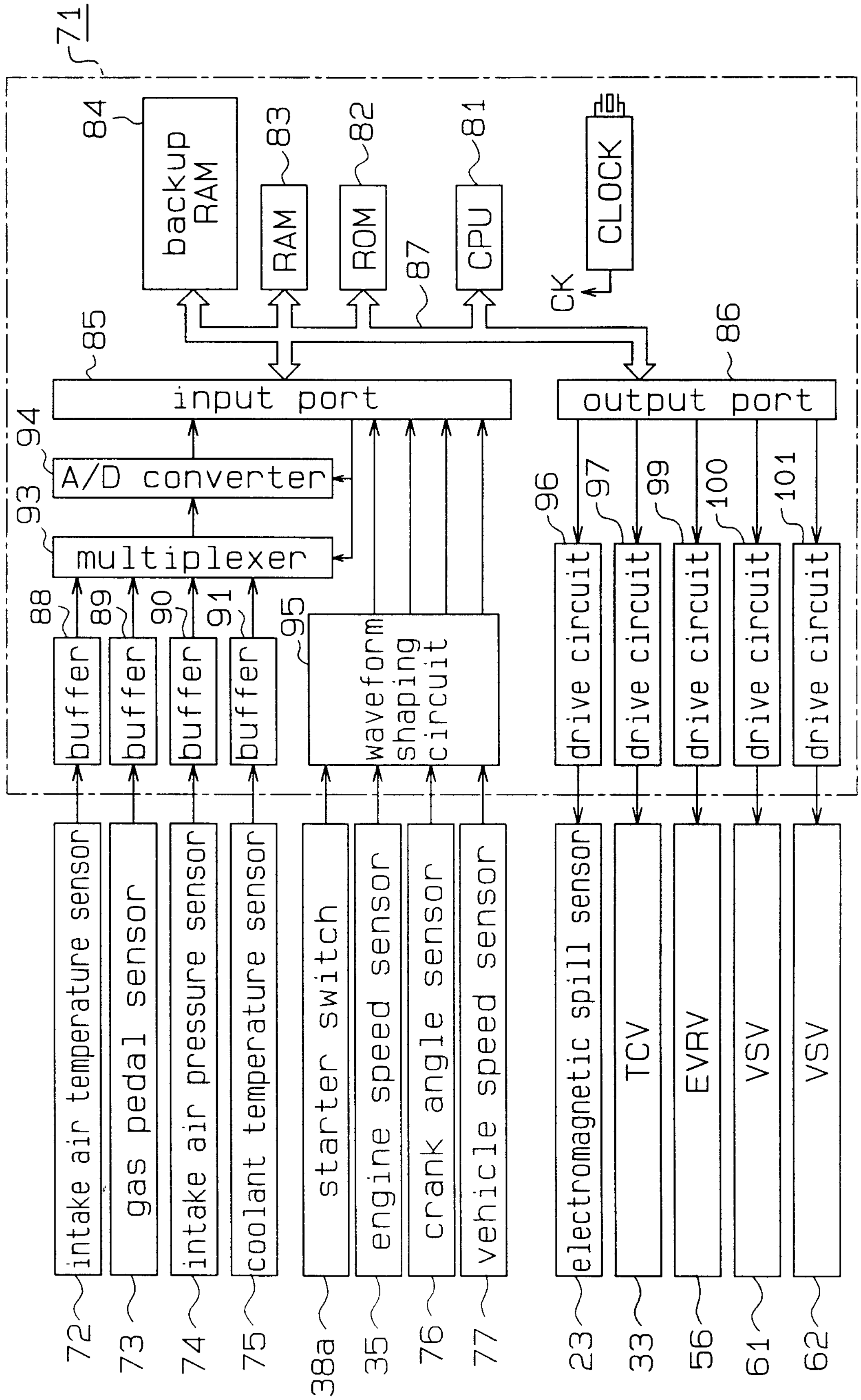
Fig.3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backup RAM
84
RAM
83
ROM
82
CPU
81
CLOCK
CK
87
input port
85
output port
86
A/D converter
94
multiplexer
93
buffer
buffer
buffer
buffer
88
89
90
91
waveform shaping circuit
95
drive circuit
drive circuit
drive circuit
drive circuit
drive circuit
96
97
99
100
101
intake air temperature sensor
gas pedal sensor
intake air pressure sensor
coolant temperature sensor
starter switch
engine speed sensor
crank angle sensor
vehicle speed sensor
electromagnetic spill sensor
TCV
EVRV
VSV
VSV
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74
75
38a
35
76
77
23
33
56
61
62

Fig.4

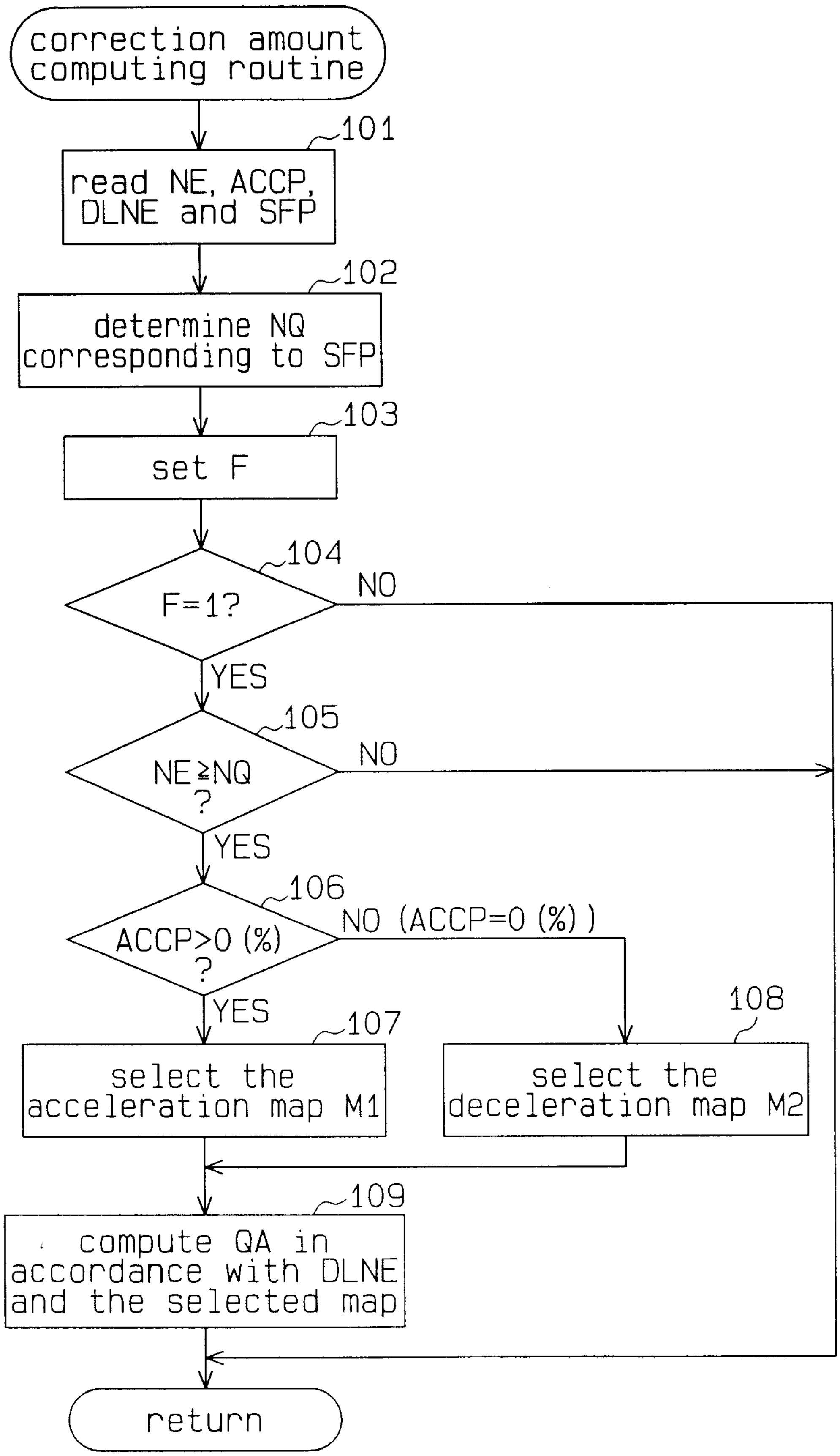
correction amount computing routine
101
read NE, ACCP, DLNE and SFP
102
determine NQ corresponding to SFP
103
set F
104
F=1?
NO
YES
105
NE≧NQ ?
NO
YES
106
ACCP>0 (%) ?
NO (ACCP=0 (%))
YES
107
select the acceleration map M1
108
select the deceleration map M2
109
compute QA in accordance with DLNE and the selected map
return

Fig.5

	1st	2nd	3rd	4th	5th
SFP	1	2	3	4	5
NQ (rpm)	700 (680)	700	850	900	1000

Fig.6

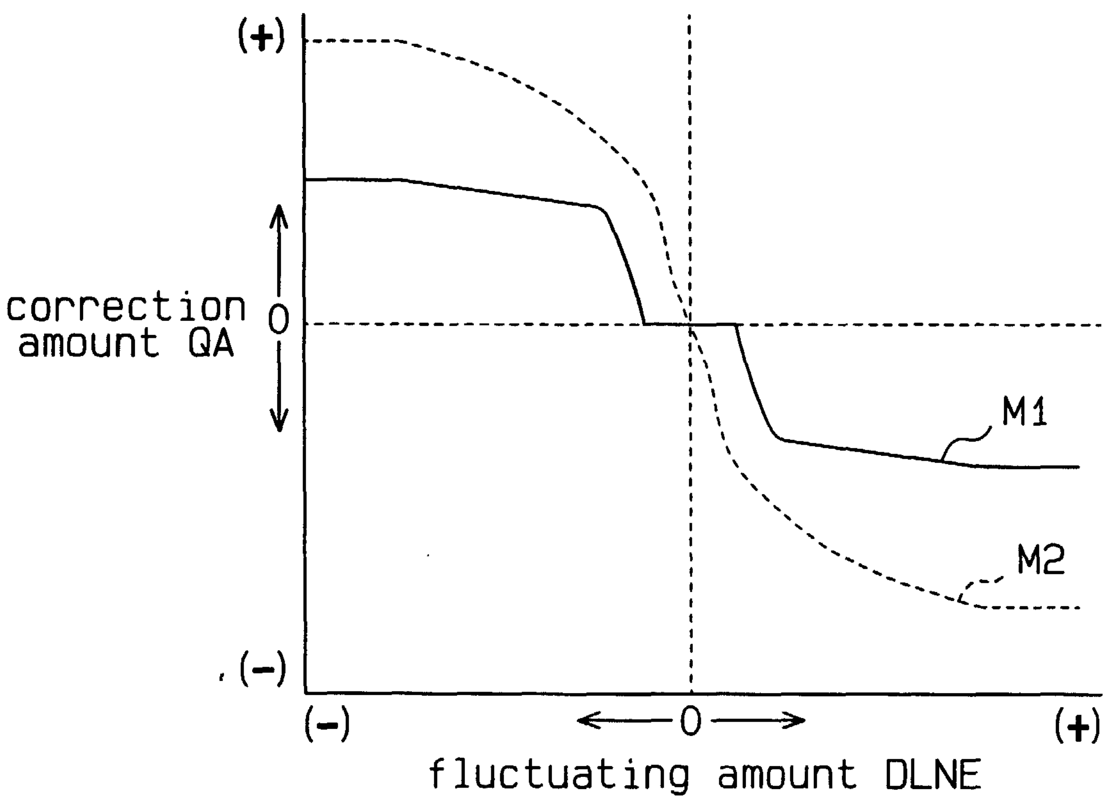

Fig.7