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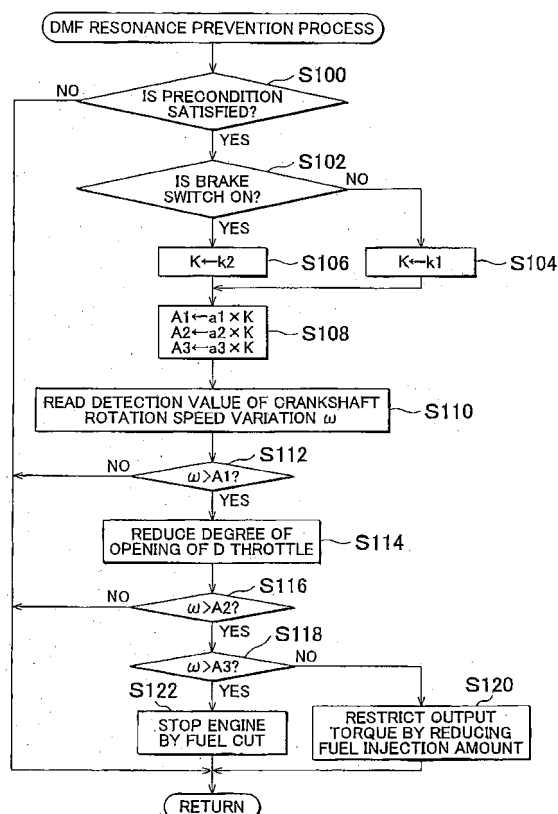
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(54) **Internal combustion engine resonance start detection system and method and internal combustion engine controller**

(57) A crankshaft rotation speed variation ω is compared with variation determination thresholds A1, A2, and A3 to suppress the magnitude of resonance of a dual mass flywheel (DMF). The variation determination thresholds A1 to A3 are set based on an operation state that reflects the intention of the vehicle's driver to accelerate or decelerate, which is, for example, a brake pedal depression operation (S102 to S108). Appropriate variation determination thresholds A1 to A3 are set regardless of whether the vehicle's driver is actually performing a braking operation or is not performing a braking operation. Thus, it is possible to appropriately detect the start of resonance of the DMF accurately based on the information on the intention of the vehicle's driver including whether or not a braking operation is being performed. Thus, it is possible to reduce or eliminate the variation of output generated by an engine, at an appropriate timing.

FIG. 2



Description**BACKGROUND OF THE INVENTION**

1. Field of the Invention

[0001] The invention relates to an internal combustion engine resonance start detection system for and method of detecting a start of resonance in an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, and also relates to an internal combustion engine controller, in which the internal combustion engine resonance start detection system is used.

2. Description of the Related Art

[0002] A technology is known, in which a dual mass flywheel is used to suppress the transmission of variation of torque of an internal combustion engine to a driving system (see Japanese Patent Application Publication No. 2005-069206 (JP-A-2005-069206) (pages 7 and 8, FIG. 8)). The dual mass flywheel is formed by connecting two flywheels via elastic bodies such as springs. Thus, there is a resonance frequency in a dual mass flywheel. When a resonance occurs, the amplitude of the relative motion between the two flywheels increases, which can cause a shock due to the bottoming of the springs or in some cases can damage the dual mass flywheel.

[0003] In order to prevent such a resonance of the dual mass flywheel, in general, a resonance point is set within a rotation speed region lower than an idle speed. However, depending on an operation state of the internal combustion engine, the rotation speed can temporarily fall below the idle speed. Thus, such setting of the resonance point is not sufficient to prevent the resonance of the dual mass flywheel.

[0004] In JP-A-2005-069206, it is described that when an engine speed remains within a resonant rotation speed range that is set based on a temperature of the engine for a predetermined period of time that is set based on the temperature of the engine, the engine speed is brought apart from the resonance rotation speed region by stopping fuel supply.

[0005] Regarding the measure against resonance caused by the engine speed as described above, a technology for preventing resonance relating to the body of the vehicle in an internal combustion engine that is not provided with the dual mass flywheel is already available (see Japanese Patent Application Publication No. 2002-221059 (JP-A-2002-221059) (pages 6 and 7, FIG. 2)).

[0006] In JP-A-2002-221059, it is described that it is determined whether the vehicle's driver intends to decelerate or accelerate, based on the amount of depression of the brake pedal and the state of the accelerator switch and, when the engine speed is in a resonant region, the engine is stopped to prevent resonance during braking and on the other hand, the engine is not stopped during accelerating so that stop and restart of the engine are not frequently repeated.

[0007] However, it is difficult to determine whether the resonance is about to start actually with the use of the engine speed only. Thus, there is a fear that an unnecessary fuel-injection-amount restricting control operation is performed despite the fact that the dual mass flywheel is not about to start resonating yet, resulting in delay of the recovery of the rotation speed from a speed lower than the idle speed and/or the increase in the frequency of engine stalls. On the other hand, there is a fear that the state, in which the fuel-injection-amount restricting control operation is not performed, continues despite the fact that the dual mass flywheel is about to start resonating and therefore, the resonance increases, which can cause a shock due to the bottoming of springs or in some cases can damage the dual mass flywheel.

[0008] In addition, the technology as described in JP-A-2002-221059, in which it is determined whether the operation to prevent the occurrence of resonance is being performed, based only on whether an operation is being performed by the vehicle's driver, cannot deal with the resonance that occurs while there is neither braking operation nor accelerating operation and therefore cannot appropriately prevent the occurrence of resonance.

SUMMARY OF THE INVENTION

[0009] An object of the invention is to appropriately detect the start of resonance of a dual mass flywheel accurately based on the information on the intention of a vehicle's driver to accelerate or decelerate, the information including whether or not an accelerating or decelerating operation is being performed, and to perform a resonance preventing process based on the result of such detection.

[0010] A first aspect of the invention is an internal combustion engine resonance start detection system for detecting a start of resonance in an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the internal combustion engine resonance start detection system being characterized by including: a crankshaft rotation speed variation detection means for detecting the magnitude of variation of a crankshaft rotation speed of the internal combustion engine; an operation state detection means for detecting an operation state

that reflects an intention of a driver of the vehicle to accelerate or decelerate and includes whether or not an operation is being performed; a variation determination threshold setting means for setting a variation determination threshold according to the operation state detected by the operation state detection means; and a resonance start determination means that determines that the start of resonance is detected, provided that the magnitude of variation detected by the crankshaft rotation speed variation detection means becomes greater than the variation determination threshold that is set by the variation determination threshold setting means.

[0011] The resonance start determination means determines the magnitude of the variation of the crankshaft rotation speed of the internal combustion engine with the use of the variation determination threshold set by the variation determination threshold setting means. The variation of the crankshaft rotation speed that reflects the actual resonance state is the subject of determination instead of determining the occurrence of resonance with the use of the engine speed alone, so that the resonance state of the dual mass flywheel is accurately determined.

[0012] In addition, the variation determination threshold is set according to the operation state obtained by detecting the state of operation reflecting the intention of the vehicle's driver to accelerate or decelerate, which includes whether or not an operation is being performed. Thus, an appropriate variation determination threshold is set not only for the resonance when the vehicle's driver is actually performing the braking or accelerating operation but also for the resonance when neither accelerating operation nor braking operation is being performed.

[0013] In this way, it is possible to appropriately detect the start of resonance of the dual mass flywheel accurately based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not an operation is being performed.

[0014] In the internal combustion engine resonance start detection system according to the first aspect, the operation state detection means may detect a braking operation state that includes whether a braking operation is being performed.

[0015] By setting the variation determination threshold according to the braking operation state which includes whether a braking operation is being performed in this way, it is possible to appropriately detect the start of resonance of the dual mass flywheel accurately based on the information on the intention of the vehicle's driver, especially the intention to decelerate, the information including whether or not an operation is being performed.

[0016] In the internal combustion engine resonance start detection system according to the first aspect, the operation state detection means may detect an accelerating operation state that includes whether an accelerating operation is being performed.

[0017] By setting the variation determination threshold according to the accelerating operation state which includes whether an accelerating operation is being performed in this way, it is possible to appropriately detect the start of resonance of the dual mass flywheel accurately based on the information on the intention of the vehicle's driver, especially the intention to accelerate, the information including whether or not an operation is being performed.

[0018] In the internal combustion engine resonance start detection system according to the first aspect, the operation state detection means may detect a braking operation state that includes whether a braking operation is being performed and an accelerating operation state that includes whether an accelerating operation is being performed.

[0019] By setting the variation determination threshold according to the operation state that includes whether a braking operation is being performed and whether an accelerating operation is being performed in this way, it is possible to appropriately detect the start of resonance of the dual mass flywheel accurately based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not an operation is being performed.

[0020] In the internal combustion engine resonance start detection system according to the first aspect, a configuration may be employed in which, when the operation state detection means detects both the accelerating operation state that indicates that the accelerating operation is being performed and the braking operation state that indicates that the braking operation is being performed at the same time, the variation determination threshold setting means sets the variation determination threshold based on the braking operation state rather than the accelerating operation state.

[0021] The braking operation state, in which the braking operation is being performed, indicates high possibility that the vehicle's driver is facing an emergency and therefore, when both the accelerating operation state that indicates that the accelerating operation is being performed and the braking operation state that indicates that the braking operation is being performed are detected at the same time, the variation determination threshold setting means sets the variation determination threshold based on the braking operation state rather than the accelerating operation state. This makes more effective the appropriate determination based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not an operation is being performed.

[0022] A second aspect of the invention is an internal combustion engine controller for an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the controller including: the internal combustion engine resonance start detection system according to the first aspect; and an output variation control means for reducing or eliminating variation of output generated by the internal combustion engine when the resonance start determination means of the internal combustion engine resonance start detection system determines that the start of resonance is detected.

[0023] The output variation control means reduces or eliminates variation of output generated by the internal com-

bustion engine when it is determined by the internal combustion engine resonance start detection system that the start of resonance is detected, so that it is possible to reduce or eliminate the resonance of the dual mass flywheel.

[0024] As described above, the variation determination threshold makes it possible to appropriately detect the start of resonance of a dual mass flywheel accurately based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not an operation is being performed. Thus, it is possible to reduce or eliminate the variation of output generated by the internal combustion engine, at an appropriate timing based on the information on the intention including whether or not an operation is being performed.

[0025] In the internal combustion engine controller according to the second aspect, the output variation control means may reduce the variation of output generated by the internal combustion engine by reducing the amount of intake air of the internal combustion engine.

[0026] When the amount of intake air of the internal combustion engine is reduced, the variation of output generated by the internal combustion engine is reduced as compared to the variation thereof before the amount of intake air is reduced. In this way, by reducing the amount of intake air, it is possible to reduce the variation of output generated by the internal combustion engine, at an appropriate timing based on the information on the intention including whether or not an operation is being performed.

[0027] In the internal combustion engine controller according to the second aspect, the internal combustion engine may be a diesel engine having a throttle valve, and the output variation control means may reduce the amount of intake air of the internal combustion engine by reducing the degree of opening of the throttle valve.

[0028] The reduction of the amount of intake air can be performed by reducing the degree of opening of the throttle valve in the case of the diesel engine having a throttle valve.

[0029] In the internal combustion engine controller according to the second aspect, the output variation control means may reduce the variation of output generated by the internal combustion engine by reducing the amount of fuel supply in the internal combustion engine.

[0030] When the amount of fuel supply in the internal combustion engine is reduced, the variation of output generated by the internal combustion engine is reduced as compared to the variation thereof before the amount of intake air is reduced. In this way, by reducing the amount of fuel supply, it is possible to reduce the variation of output generated by the internal combustion engine, at an appropriate timing based on the information on the intention including whether or not an operation is being performed.

[0031] In the internal combustion engine controller according to the second aspect, the output variation control means may reduce or eliminate the variation of output generated by the internal combustion engine by stopping fuel supply in the internal combustion engine.

[0032] When the fuel supply is stopped, the variation of output generated by the internal combustion engine is reduced. When the internal combustion engine is then stopped, the output variation is eliminated. By stopping the fuel injection, it is possible to reduce or eliminate the variation of output generated by the internal combustion engine, at an appropriate timing based on the information on the intention including whether or not an operation is being performed. In addition, the internal combustion engine is rapidly brought toward stoppage and the engine speed quickly passes the resonance point. In this way, it is possible to more reliably prevent the occurrence of shock and the damage of the dual mass flywheel.

[0033] In the internal combustion engine controller according to the second aspect, the output variation control means may reduce or eliminate the variation of output generated by the internal combustion engine by performing two of or all of a process of reducing the amount of intake air of the internal combustion engine, a process of reducing the amount of fuel supply in the internal combustion engine, and a process of stopping the fuel supply in the internal combustion engine.

[0034] By performing such processes in combination, it is possible to reduce or eliminate the variation of output generated by the internal combustion engine, at an appropriate timing based on the information on the intention of the vehicle's driver including whether or not an operation is being performed.

[0035] In the internal combustion engine controller according to the second aspect, the internal combustion engine may be a diesel engine; and the fuel supply may be fuel injection into a combustion chamber performed by a fuel injection valve.

[0036] When the internal combustion engine is a diesel engine, it is possible to reduce or eliminate the variation of output generated by the internal combustion engine by reducing the amount of the fuel injection from the fuel injection valve into the combustion chamber or stopping the same fuel injection.

[0037] A third aspect of the invention is an internal combustion engine controller for an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, including: the internal combustion engine resonance start detection system according to the first aspect; and an output variation control means for changing the frequency of the variation, with crank angle, of output generated by the internal combustion engine when the resonance start determination means of the internal combustion engine resonance start detection system determines that the start of resonance is detected.

[0038] When the resonance start determination means determines that the start of resonance is detected, the output variation control means changes the frequency of the variation of output with crank angle. More specifically, the frequency

of the variation of output when the horizontal axis indicates crank angle values, is changed. Such a change is performed by controlling the fuel injection amount or the fuel injection timing and therefore, it is possible to quickly change the frequency of the variation of output without changing the crankshaft rotation speed. As a result, it is also possible to quickly change the frequency of the variation of output along time axis. Thus, it is possible to immediately bring the output variation frequency apart from the resonance point of the dual mass flywheel. In this way, it is possible to reduce or eliminate the resonance of the dual mass flywheel.

[0039] As described above, the variation determination threshold makes it possible to appropriately detect the start of resonance of a dual mass flywheel accurately based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not an operation is being performed. Thus, it is possible to reduce or eliminate the variation of output generated by the internal combustion engine, at an appropriate timing based on the information on the intention including whether or not an operation is being performed.

[0040] In the internal combustion engine controller according to the third aspect, the internal combustion engine may include a plurality of cylinders; the fuel supply into a combustion chamber of each of the cylinders may be performed by fuel injection into the combustion chamber; and the output variation control means may change the frequency of the variation, with crank angle, of output generated by the internal combustion engine by causing one of or both of a difference in fuel injection timing between the cylinders and a difference in fuel injection amount between the cylinders.

[0041] By providing the difference in fuel injection timing between the cylinders and the difference in fuel injection amount between the cylinders, it becomes possible to change the frequency of the variation of output with crank angle from that when the fuel injection timing and the fuel injection amount are uniformly controlled for all the cylinders. As a result, the output variation frequency along time axis is also changed. Thus, it is possible to accurately detect the start of resonance of the dual mass flywheel and suppress the resonance by quickly bringing the output variation frequency apart from the resonance point, at an appropriate timing based on the information on the intention including whether or not an operation is being performed.

[0042] The internal combustion engine controller according to the second or third aspect may further include a rotation speed detection means for detecting an engine speed of the internal combustion engine, wherein: a reference rotation speed is set lower than an engine-stall prevention determination rotation speed set to prevent engine stall and higher than a resonant rotation speed of the dual mass flywheel; and the output variation control means acts when the engine speed detected by the rotation speed detection means is lower than the reference rotation speed.

[0043] The output variation control means may be caused to act, on such a precondition. Because the reference rotation speed is lower than the engine-stall prevention rotation speed, the process of reducing or eliminating the variation of output generated by the internal combustion engine is executed after the engine speed falls below the engine-stall prevention determination rotation speed. Thus, it is possible to avoid the occurrence of resonance of the dual mass flywheel without impairing the existing performance of preventing engine stall, at an appropriate timing based on the information on the intention including whether or not an operation is being performed.

[0044] In the internal combustion engine controller according to the second or third aspect, the output variation control means may act when the vehicle is in a braking operation.

[0045] The output variation control means may be caused to act, on the condition that the vehicle is in a braking operation. With this configuration, it is possible to distinguish the variation of the crankshaft rotation speed from that occurring during acceleration and therefore, it is possible to more accurately detect the start of resonance of a dual mass flywheel during a braking operation.

[0046] In the internal combustion engine controller according to the second or third aspect, the output variation control means may act when at least one of a condition that a vehicle speed is equal to or lower than a reference vehicle speed and a condition that the engine speed is equal to or lower than the reference rotation speed is satisfied and a clutch is in an engagement state or in a partial engagement state.

[0047] The output variation control means may be caused to act, on the condition that at least one of a condition that a vehicle speed is equal to or lower than a reference vehicle speed and a condition that the engine speed is equal to or lower than the reference rotation speed is satisfied and a clutch is in an engagement state or in a partial engagement state. With this configuration, it is possible to detect the reduction in rotation speed when the clutch is engaged at the time of starting the vehicle and it is therefore possible to accurately detect the start of resonance of the dual mass flywheel at the time of starting the vehicle.

[0048] In the internal combustion engine controller according to the second or third aspect, the output variation control means may act when the vehicle is climbing a slope.

[0049] The output variation control means may be caused to act, on the condition that the vehicle is climbing a slope. With this configuration, it is possible to detect the reduction in rotation speed at the time of climbing a slope and it is therefore possible to accurately detect the start of resonance of the dual mass flywheel during climbing a slope.

[0050] A fourth aspect of the invention is an internal combustion engine controller for an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, including: a clutch sensor that detects an engagement state of a clutch that is disposed between the dual mass flywheel and the driving system; the

internal combustion engine resonance start detection system according to the first aspect; and a notification means that outputs notification to request disengagement of the clutch when the clutch sensor detects continuation of the engagement state or the partial engagement state of the clutch and the resonance start determination means of the internal combustion engine resonance start detection system determines that the start of resonance is detected.

[0051] When the resonance start determination means determines that the start of resonance is detected, the notification is output by the notification means based on this determination. If the vehicle's driver disengages the clutch in response to this notification, the rotation speed of the internal combustion engine is prevented from falling to the resonance point and therefore, it is possible to reduce or eliminate the resonance of the dual mass flywheel.

[0052] As described above, the variation determination threshold used by the resonance start determination means makes it possible to appropriately detect the start of resonance of a dual mass flywheel accurately based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not an operation is being performed. Thus, it is possible to output notification to request disengagement of the clutch at an appropriate timing. Because it is possible to output the notification in this way, it is possible to reduce or eliminate the variation of output generated by the internal combustion engine at an appropriate timing.

[0053] In the internal combustion engine controller according to the fourth aspect, the notification means may output the notification by lighting a warning lamp. By outputting the notification in this way, it is possible to request the vehicle's driver to disengage the clutch.

[0054] In the internal combustion engine controller according to the fourth aspect, the notification means may act when an engine speed of the internal combustion engine is equal to or lower than a reference rotation speed.

[0055] The notification means may be caused to act, on the condition that the engine speed of the internal combustion engine is equal to or lower than the reference rotation speed. With this configuration, it is possible to accurately detect the start of resonance of the dual mass flywheel that occurs when the engine speed becomes low and it is therefore possible to take a measure at an appropriate timing.

[0056] The internal combustion engine controller according to the fourth aspect may further include: a rotation speed detection means for detecting an engine speed of the internal combustion engine; and an internal combustion engine output increasing means that increases the output from the internal combustion engine when the engine speed detected by the rotation speed detection means is lower than a reference rotation speed when the notification means outputs the notification.

[0057] When the engine speed of the internal combustion engine is lower than the reference rotation speed while the engagement state or the partial engagement state of the clutch continues in spite of the output of the notification, the internal combustion engine output increasing means increases the output from the internal combustion engine. Thus, it is possible to prevent the engine speed of the internal combustion engine from falling to the resonance point of the dual mass flywheel even before the driver disengages the clutch. Thus, it is possible to effectively reduce or eliminate the resonance of the dual mass flywheel.

[0058] A fifth aspect of the invention is an internal combustion engine resonance start detection method of detecting a start of resonance in an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the internal combustion engine resonance start detection method being characterized by including: detecting the magnitude of variation of a crankshaft rotation speed of the internal combustion engine; detecting an operation state that reflects an intention of a driver of the vehicle to accelerate or decelerate and includes whether or not an operation is being performed; setting a variation determination threshold according to the detected operation state; and determining that the start of resonance is detected, provided that the detected magnitude of variation becomes greater than the set variation determination threshold.

[0059] In the internal combustion engine resonance start detection method according to the fifth aspect, in detecting the operation state, a braking operation state that includes whether a braking operation is being performed may be detected.

[0060] In the internal combustion engine resonance start detection method according to the fifth aspect, in detecting the operation state, an accelerating operation state that includes whether an accelerating operation is being performed may be detected.

[0061] In the internal combustion engine resonance start detection method according to the fifth aspect, in detecting the operation state, a braking operation state that includes whether a braking operation is being performed and an accelerating operation state that includes whether an accelerating operation is being performed may be detected.

[0062] In the internal combustion engine resonance start detection method according to the fifth aspect, a configuration may be employed in which, in setting the variation determination threshold, when both the accelerating operation state that indicates that the accelerating operation is being performed and the braking operation state that indicates that the braking operation is being performed are detected at the same time, the variation determination threshold is set based on the braking operation state rather than the accelerating operation state.

[0063] A sixth aspect of the invention is an internal combustion engine control method of controlling an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the method

including: the internal combustion engine resonance start detection method according to the fifth aspect; and reducing or eliminating variation of output generated by the internal combustion engine when it is determined that the start of resonance is detected.

[0064] In the internal combustion engine control method according to the sixth aspect, in reducing or eliminating the variation of output, the variation of output generated by the internal combustion engine may be reduced by reducing the amount of intake air of the internal combustion engine.

[0065] In the internal combustion engine control method according to the sixth aspect, the internal combustion engine may be a diesel engine having a throttle valve; and, in reducing or eliminating the variation of output, the amount of intake air of the internal combustion engine may be reduced by reducing the degree of opening of the throttle valve.

[0066] In the internal combustion engine control method according to the sixth aspect, in reducing or eliminating the variation of output, the variation of output generated by the internal combustion engine may be reduced by reducing the amount of fuel supply in the internal combustion engine.

[0067] In the internal combustion engine control method according to the sixth aspect, in reducing or eliminating the variation of output, the variation of output generated by the internal combustion engine may be reduced or eliminated by stopping fuel supply in the internal combustion engine.

[0068] In the internal combustion engine control method according to the sixth aspect, in reducing or eliminating the variation of output, the variation of output generated by the internal combustion engine may be reduced or eliminated by performing two of or all of a process of reducing the amount of intake air of the internal combustion engine, a process of reducing the amount of fuel supply in the internal combustion engine, and a process of stopping the fuel supply in the internal combustion engine.

[0069] In the internal combustion engine control method according to the sixth aspect, the internal combustion engine may be a diesel engine; and the fuel supply may be fuel injection into a combustion chamber performed by a fuel injection valve.

[0070] A seventh aspect of the invention is an internal combustion engine control method of controlling an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, including: the internal combustion engine resonance start detection method according to the fifth aspect; and changing the frequency of the variation, with crank angle, of output generated by the internal combustion engine when it is determined that the start of resonance is detected.

[0071] In the internal combustion engine control method according to the seventh aspect, the internal combustion engine may include a plurality of cylinders; the fuel supply into a combustion chamber of each of the cylinders may be performed by fuel injection into the combustion chamber; and in reducing or eliminating the variation of output, the frequency of the variation, with crank angle, of output generated by the internal combustion engine may be changed by causing one of or both of a difference in fuel injection timing between the cylinders and a difference in fuel injection amount between the cylinders.

[0072] The internal combustion engine control method according to the sixth or seventh aspect may further include detecting an engine speed of the internal combustion engine, wherein: a reference rotation speed is set lower than an engine-stall prevention determination rotation speed set to prevent engine stall and higher than a resonant rotation speed of the dual mass flywheel; and when the rotation speed detected by the rotation speed detection means is lower than the reference rotation speed.

[0073] In the internal combustion engine control method according to the sixth or seventh aspect, the variation of output may be reduced or eliminated when the vehicle is in a braking operation.

[0074] In the internal combustion engine control method according to the sixth or seventh aspect, the variation of output may be reduced or eliminated when at least one of a condition that a vehicle speed is equal to or lower than a reference vehicle speed and a condition that the engine speed is equal to or lower than the reference rotation speed is satisfied and a clutch is in an engagement state or in a partial engagement state.

[0075] In the internal combustion engine control method according to the sixth or seventh aspect, the variation of output may be reduced or eliminated when the vehicle is climbing a slope.

[0076] An eighth aspect of the invention is an internal combustion engine control method of controlling an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, including: detecting an engagement state of a clutch that is disposed between the dual mass flywheel and the driving system; the internal combustion engine resonance start detection method according to the fifth aspect; and outputting notification to request disengagement of the clutch when the clutch sensor detects continuation of the engagement state or the partial engagement state of the clutch and it is determined that the start of resonance is detected.

[0077] In the internal combustion engine control method according to the eighth aspect, the notification may be output by lighting a warning lamp.

[0078] In the internal combustion engine control method according to the eighth aspect, the notification may be output when an engine speed of the internal combustion engine is equal to or lower than a reference rotation speed.

[0079] The internal combustion engine control method according to the eighth aspect may further include: detecting

an engine speed of the internal combustion engine; and increasing the output from the internal combustion engine when the detected engine speed is lower than a reference rotation speed when the notification is output.

BRIEF DESCRIPTION OF THE DRAWINGS

[0080] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a block diagram showing a schematic configuration of an internal combustion engine of a first embodiment, and a driving system and a control system thereof;
 FIG. 2 shows a flow chart of a DMF resonance prevention process that is executed by an ECU of the first embodiment;
 FIG. 3 shows a flow chart of a process of detecting a crankshaft rotation speed variation ω ;
 FIG. 4 shows a timing chart showing an example of control according to the first embodiment;
 FIG. 5 shows a timing chart showing an example of the control according to the first embodiment;
 FIG. 6 shows a flowchart of a DMF resonance prevention process of a second embodiment;
 FIG. 7 shows a timing chart showing an example of control according to the second embodiment;
 FIG. 8 shows a timing chart showing an example of the control according to the second embodiment;
 FIG. 9 shows a graph for explaining the content of a map MAPbp used in a third embodiment;
 FIG. 10 shows a timing chart showing an example of control according to the third embodiment;
 FIG. 11 shows a flow chart of a DMF resonance prevention process of a fourth embodiment;
 FIG. 12 shows a graph showing an example of a process of changing the frequency of the variation of output with crank angle, according to the fourth embodiment;
 FIG. 13 shows a graph showing an example of the process of changing the frequency of the variation of output with crank angle, according to the fourth embodiment;
 FIG. 14 shows a flow chart of a DMF resonance prevention notification process of a fifth embodiment;
 FIG. 15 shows a timing chart showing an example of control according to the fifth embodiment;
 FIG. 16 shows a timing chart showing an example of the control according to the fifth embodiment; and
 FIG. 17 shows a flow chart of a DMF resonance prevention process of a sixth embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

(First Embodiment)

[0081] FIG. 1 is a block diagram showing a schematic configuration of a diesel engine (hereinafter abbreviated as the "engine"), which serves as a vehicle-driving internal combustion engine, to which the invention is applied, and the driving system and the control system thereof. The engine 2 is an in-line four-cylinder engine, in which each of the cylinders is provided with a fuel injection valve 4 that directly injects fuel into the combustion chamber.

[0082] The fuel injection valve 4 is connected to a common rail 6 that pressurizes the fuel to a predetermined pressure. The common rail 6 is supplied with pressurized fuel from a fuel pump that is driven by the engine 2. The pressurized fuel that is distributed among the fuel injection valves 4 of the cylinders by the common rail 6 is injected from the fuel injection valves 4 into the cylinder following the fuel injection valves 4 being opened by applying a predetermined amount of electric current to the fuel injection valves 4.

[0083] An intake manifold 8 is connected to the engine 2 and branching pipes of the intake manifold 8 are connected to the combustion chambers of the respective cylinders via intake ports. The intake manifold 8 is connected to an intake pipe 10, a diesel throttle valve (hereinafter referred to as the "D throttle") 12 that throttles the intake air is provided in the intake pipe 10 and the degree of opening of the D throttle 12 is adjusted by an electric actuator 14. An intercooler, a compressor of a turbocharger, and an air cleaner are disposed upstream of the intake pipe 10.

[0084] An exhaust gas recirculation passage (EGR passage) 16 opens into the intake pipe 10 downstream of the D throttle 12. The EGR passage 16 introduces, at the upstream side thereof, part of the exhaust gas that flows the exhaust gas passage of the engine 2. In this way, the EGR passage 16 introduces the exhaust gas, as the EGR gas, into the intake pipe 10 through an EGR valve 18 for regulating flow rate.

[0085] Note that, on the exhaust passage side, the energy of flow of the exhaust gas rotates a turbine of the turbocharger. The exhaust gas that rotated the turbine is treated in an exhaust gas control catalyst and discharged. The output of the engine 2 is transmitted to a manual transmission (hereinafter abbreviated as the "MT") 28 via a dual mass flywheel (hereinafter abbreviated as the "DMF") 24 including a primary flywheel 20 and a secondary flywheel 22, and a clutch 26 provided on the secondary flywheel 22 side.

[0086] The DMF 24 is formed by connecting the primary flywheel 20 and the secondary flywheel 22 via springs 24a,

and respective rotary shafts 20a and 22a of the primary flywheel 20 and the secondary flywheel 22 are relatively rotatably connected via a bearing 24b. The output of the engine 2 is transmitted from a crankshaft 2a to the MT 28 via the DMF 24 and at the same time, the output variation of the engine 2 is effectively absorbed and reduced by the springs 24a. Thus, it is possible to suppress the torsional vibration of the driving system during normal operation and it is possible to effectively reduce or avoid the occurrence of noise and vibration due to the torsional vibration.

[0087] An electronic control unit (ECU) 30 for controlling the operating conditions of the engine is provided for the engine 2. The ECU 30 is a control circuit that controls the operating conditions of the engine according to the operating conditions of the engine and the demand from the driver. The ECU 30 has a microcomputer as a main component, which includes a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), a back-up RAM, etc.

[0088] The ECU 30 receives signals from a crankshaft rotation speed sensor 32 (which functions as the rotation speed detection means) for detecting the rotation speed (rpm) of the crankshaft 2a, and an opening degree sensor 34 for detecting the degree of opening of the D throttle 12. In addition, the ECU 30 receives signals from a vehicle speed sensor, an accelerator operation amount sensor, a brake switch, a clutch switch, an intake air amount sensor, a fuel pressure sensor, and other sensors and switches.

[0089] The ECU 30 adjusts the fuel injection amount, the fuel injection timing, the degree of opening of the D throttle 12, the degree of opening of the EGR valve 18, etc. with the use of such detection data and various arithmetic operations for control. Note that the information for notifying the driver of the conditions of the vehicle and the engine 2 as needed is displayed by LCDs and lamps on a display 36 provided on a dashboard.

[0090] A DMF resonance prevention process that is executed by the ECU 30 is shown by the flowchart in FIG. 2. This process is executed as interrupts at certain time intervals. Note that each step in the flowchart corresponding to the individual process is represented by the character "S" (step 100 is represented by S100, for example).

[0091] When the DMF resonance prevention process (FIG. 2) is started, it is determined whether a precondition is satisfied (S100). In this case, the precondition is a logical "OR" condition that the engine speed NE detected by the crankshaft rotation speed sensor 32 is lower than a reference rotation speed OR the vehicle speed detected by the vehicle speed sensor is lower than the reference vehicle speed. Note that the precondition may be that the engine speed NE detected by the crankshaft rotation speed sensor 32 is lower than the reference rotation speed, alone. Alternatively, the condition may be made more strict, that is, the condition may be a logical "AND" condition that the engine speed NE detected by the crankshaft rotation speed sensor 32 is lower than a reference rotation speed AND the vehicle speed detected by the vehicle speed sensor is lower than the reference vehicle speed.

[0092] The reference rotation speed is set in advance at a speed that is lower than an engine-stall prevention determination rotation speed set to prevent engine stall and is higher than a resonant rotation speed of the DMF 24, according to the type of the engine 2. The reference vehicle speed is set within a low-speed range corresponding to the situation where the vehicle is about to start or stop, for example.

[0093] The precondition in S100 is a condition set to avoid the problem of resonance of the DMF 24 without impairing the engine stall prevention performance. Another additional logical "OR" condition(s) may be added to the precondition as described in the section of "Other Embodiments" below.

[0094] When the precondition is not satisfied (NO in S100), the process is temporarily exited. When the condition is satisfied (YES in S100), it is then determined whether the brake switch is on (S102). Specifically, for example, it is determined whether the driver of the vehicle is depressing the brake pedal to apply braking.

[0095] When the brake switch is off (NO in S102), it is determined that the intention of the vehicle's driver to accelerate or decelerate is a non-braking intention, which includes the intention to accelerate, and a variation determination threshold correction coefficient K is set to a first correction coefficient k1 (S104).

[0096] When the brake switch is on (YES in S102), the intention of the vehicle's driver to accelerate or decelerate is a braking intention and the variation determination threshold correction coefficient K is set to a second correction coefficient k2 (S106). The first and second correction coefficients k1 and k2 are in the following relation:

first correction coefficient k1 > second correction coefficient k2.

[0097] The variation determination threshold correction coefficient K is set in S104 or S106, three variation determination thresholds A1, A2, and A3 are calculated as shown by the following Expressions 1 to 3 with the use of the variation determination threshold correction coefficient K (S108).

(Expression 1)

$$A1 \leftarrow a1 \times K$$

(Expression 2)

$$A2 \leftarrow a2 \times K$$

(Expression 3)

$$A3 \leftarrow a3 \times K$$

[0098] The variation determination threshold reference values $a1$, $a2$, and $a3$ are reference values for setting three thresholds used to determine at which level in the early stage of resonance a crankshaft rotation speed variation ω is. The values $a1$ to $a3$ are set according to the kind of the engine 2 and the driving system thereof in advance. Note that the first to third variation determination threshold reference values $a1$ to $a3$ are in the following relation: first variation determination threshold reference value $a1$ < second variation determination threshold reference value $a2$ < third variation determination threshold reference value $a3$.

[0099] Thus, the above Expressions 1 to 3 set three levels of the variation determination thresholds $A1$, $A2$, and $A3$ based on the intention of the vehicle's driver to accelerate or decelerate. Next, the detection value of the rotation speed variation ω of the crankshaft 2, which corresponds to the magnitude of the variation, is read into the working area provided in the RAM in the ECU 30 (S110). The detection of the crankshaft rotation speed variation ω is a value that is detected by the process of detecting the crankshaft rotation speed variation ω shown by the flow chart in FIG 3. The process of detecting the crankshaft rotation speed variation w will now be described (FIG. 3). This process is executed as an interrupt every time a pulse is output from the crankshaft rotation speed sensor 32.

[0100] Upon start of the process of detecting the crankshaft rotation speed variation ω (FIG. 3), a pulse time interval T of the crankshaft rotation speed sensor 32 is read into the working area in the RAM (S152). The crankshaft rotation speed sensor 32 outputs a pulse signal to the ECU 30 every time the crankshaft 2a rotates a predetermined angle, which is 10°CA (CA: crank angle) in this embodiment. In the ECU 30, a process of measuring the time interval T of the pulse signals corresponding to a rotation of the predetermined angle every time a pulse signal is input (that is, per 10°CA rotation), is executed. In S152, the pulse time interval T thus measured is read.

[0101] As shown by the following Expression 4, the absolute value of the difference between the pulse time interval T read in the current control cycle and the pulse time interval T_{old} read in the preceding control cycle is calculated as a time interval variation dT .

(Expression 4)

$$dT \leftarrow |T - T_{old}|$$

[0102] Next, it is determined whether the time interval variation dT calculated in the current control cycle is equal to or less than the time interval variation dT calculated in the preceding control cycle (S156). When $dT > dT_{old}$ (NO in S156), the time interval variation dT_{old} calculated in the preceding control cycle is set as the time interval variation dT_{old2} calculated in the control cycle preceding the preceding control cycle (S162). Subsequently, the time interval variation dT calculated in the current control cycle is set as the time interval variation dT_{old} calculated in the preceding control cycle (S164). Then, the pulse time interval T of the current control cycle is set as the pulse time interval T_{old} of the preceding control cycle (S166) and the process is temporarily exited.

[0103] When it is determined in S156 that dT is equal to or lower than dT_{old} (YES in S156), it is determined whether the time interval variation dT_{old} calculated in the preceding control cycle is greater than the time interval variation dT_{old2} calculated in the cycle receding the preceding control cycle (S158). When $dT_{old} > dT_{old2}$ (NO in S158), the process from S162 to S166 is executed as described above and the process is temporarily exited.

[0104] When it is determined in S158 that $dTold > dTold2$ (YES in S158), the time interval variation $dTold$ calculated in the preceding control cycle is set as the crankshaft rotation speed variation ω (S160).

[0105] Specifically, when the determination in S156 is affirmative (YES) and the determination in S158 is affirmative (YES), the three time interval variations dT , $dTold$, and $dTold2$ that are consecutively detected satisfy the following relation: $dT \leq dTold > dTold2$.

[0106] The higher the rotation speed of the crankshaft 2a is, the shorter the time intervals of the pulses output by the crankshaft rotation speed sensor 32 are. The lower the rotation speed of the crankshaft 2a is, the longer the time intervals of the pulses output by the crankshaft rotation speed sensor 32 are. Specifically, the pulse time interval T is a physical quantity corresponding to the rotation speed of the crankshaft 2a. The variation of the pulse time intervals is a physical quantity corresponding to the acceleration of rotation of the crankshaft. Thus, the peak value of the crankshaft rotational acceleration is detected in the form of the local maximum value of the absolute value of the variation of the pulse time intervals.

[0107] The greater the absolute value of the peak value of the rotational acceleration is, the greater the rotation speed variation is. The smaller the absolute value of the peak value of the rotational acceleration is, the smaller the rotation speed variation is. Thus, the local maximum value of the time interval variation dT may be regarded as a physical quantity that represents the variation of the crankshaft rotation speed. Thus, the time interval variation $dTold$ calculated in the preceding control cycle in S160 is set as the crankshaft rotation speed variation ω because it has been determined that the time interval variation $dTold$ calculated in the preceding control cycle is the local maximum value (peak value). Note that the reason why the condition includes the case where $dT = dTold$ in step S156 is because the case is taken into consideration where the pulse intervals that are detected at the peak portion of the rotational acceleration become substantially constant.

[0108] In the following control cycles, the process of detecting the crankshaft rotation speed variation ω (FIG. 3) is executed every time the crankshaft rotation speed sensor 32 outputs a pulse. When the peak value of the time interval variation dT is found (YES in S156 AND YES in S158), the crankshaft rotation speed variation ω is updated by the value (the value of the time interval variation dT calculated in the preceding control cycle) (S160).

[0109] Returning back to the description of the DMF resonance prevention process (FIG. 2), when the crankshaft rotation speed variation ω is read in S110, it is determined whether the crankshaft rotation speed variation ω is greater than the first variation determination threshold $A1$ (S112). The first variation determination threshold $A1$ is a threshold set in S108 and is the first threshold that indicates that the engine speed NE approaches the resonant rotation speed of the DMF 24.

[0110] When $\omega \leq A1$ (NO in S112), it is determined that the crankshaft rotation speed variation ω is sufficiently small and there is no fear of resonance occurring in the DMF 24, and the process is temporarily exited. When $\omega > A1$ (YES in S112), the degree of opening of the D throttle 12 is reduced by the electric actuator 14 at a predetermined rate (S114). In this way, the variation of output of the engine 2 is suppressed. Thus, the resonance of the DMF 24 is also suppressed.

[0111] Next, it is determined whether the crankshaft rotation speed variation ω is greater than the second variation determination threshold $A2$ (S116). The second variation determination threshold $A2$ is a threshold set in S108 and is greater than the first variation determination threshold $A1$. The second variation determination threshold $A2$ is a variation determination threshold that indicates that the engine speed NE further approaches the resonant rotation speed of the DMF 24 than the first variation determination threshold $A1$ indicates.

[0112] When $\omega \leq A2$ (NO in S116), it is determined that resonance is sufficiently suppressed by reducing the degree of opening of the D throttle 12 and the process is temporarily exited. When $\omega > A2$ (YES in S116), it is determined whether the crankshaft rotation speed variation ω is greater than the third variation determination threshold $A3$ (S118). The third variation determination threshold $A3$ is a threshold set in S108 and is greater than the second variation determination threshold $A2$. The third variation determination threshold $A3$ is a variation determination threshold that indicates that the engine speed NE further approaches the resonant rotation speed of the DMF 24 than the second variation determination threshold $A2$ indicates.

[0113] When $\omega \leq A3$ (NO in S118), the engine output is restricted by reducing the fuel injection amount (S120). The fuel injection amount reduction step (S120) is performed in addition to the D throttle opening degree reduction step (S114) and therefore, the variation of engine output is further suppressed and resonance of the DMF 24 is suppressed.

[0114] When $\omega > A3$ (YES in S118), the fuel is cut, that is, the fuel injection is stopped (S122). In this way, a step that is more effective than that performed in the case of $\omega \leq A3$, is performed. Because the fuel cut (S122) is performed in addition to the D throttle opening degree reduction step (S114), the engine speed NE quickly passes the resonance point of the DMF 24 and the engine stops. Thus, it is possible to prevent the resonance of the DMF 24 from becoming intense in the course of reduction of the engine speed NE to cause a failure of the DMF 24.

[0115] The timing chart of FIG. 4 shows an example of control according to the first embodiment. Before timing $t0$, even in the idle-walk state, the precondition is not satisfied because engine speed $NE \geq$ reference rotation speed AND vehicle speed $\geq$ reference vehicle speed (NO in S100). At timing $t0$, the engine speed NE becomes lower than the reference rotation speed and thus, the precondition is satisfied (YES in S100).

[0116] Before timing t_0 , crankshaft rotation speed variation $\omega \leq$ first variation determination threshold A1 (NO in S112) and therefore, it is determined that there is no fear of resonance occurring in the DMF 24, and reduction of the engine output is not performed.

[0117] At timing t_0 , ω becomes higher than A1 (YES in S112), the degree of opening of the D throttle 12 is reduced to throttle the intake air (S114). Note that in this example, despite reducing the degree of opening of the D throttle 12 at a predetermined rate, the crankshaft rotation speed variation ω gradually increases.

[0118] Then, at timing t_1 , ω becomes higher than A2 (YES in S112, YES in S116, AND NO in S118), the intake air is throttled via the D throttle 12 (S114) and the fuel injection amount is reduced (S120). Note that in this example, despite reducing the degree of opening of the D throttle 12 and the fuel injection amount, the crankshaft rotation speed variation ω gradually increases.

[0119] At timing t_2 , ω becomes higher than A3 (YES in S112, YES in S116, AND YES in S118) and therefore, the intake air is throttled via the D throttle 12 (S114) and fuel cut is performed (S122).

[0120] In FIG. 4, the broken line in the graph of the engine speed NE shows an example in which the DMF resonance prevention process (FIG. 2) is not performed and a large resonance occurs in the end. FIG. 5 shows an example in which the brake switch is turned from off to on at timing t_{10} . In response to this, the second correction coefficient k_2 that is smaller than the corresponding coefficient used when the brake switch is off is set as the variation determination threshold correction coefficient K (S106). In this way, in the above Expressions 1 to 3, the three variation determination thresholds A1, A2, and A3 are reduced as compared to those before timing t_{10} . Thus, the timing, at which the determination in S112, S116, and S118 becomes affirmative (YES), is advanced. In this way, the measure to prevent the resonance is taken earlier. In the example shown in FIG. 5, the engine 2 is stopped earlier than it is stopped in the case shown in FIG. 4.

[0121] In the above configuration, the ECU 30 functions as the crankshaft rotation speed variation detection means, the variation determination threshold setting means, and the resonance start determination means of the internal combustion engine resonance start detection system, and also functions as these means and the output variation control means of the internal combustion engine controller. The brake switch functions as the operation state detection means. The process of detecting the crankshaft rotation speed variation ω (FIG. 3) functions as the crankshaft rotation speed variation detection means. In the DMF resonance prevention process (FIG. 2), S102 to S108 function as the variation determination threshold setting means, S110, S112, S116, and S118 function as the resonance start determination means, and S100, S114, S120, and S122 function as the output variation control means.

[0122] According to the above-described first embodiment, the following effects are obtained. (i) When the resonance of the DMF 24 occurs, the vibratory variation that originally exists in the rotation speed of the crankshaft 2a is amplified. Thus, the crankshaft rotation speed variation ω detected by the process of detecting the crankshaft rotation speed variation ω (FIG. 3) is compared with the variation determination thresholds A1, A2, and A3 and may be considered as the magnitude of resonance of the DMF 24.

[0123] When such a crankshaft rotation speed variation ω exceeds the variation determination thresholds A1, A2, and A3, the engine output variation is reduced or eliminated by the DMF resonance prevention process (FIG. 2) according to the magnitude. In this way, it is possible to reduce or eliminate the resonance of the DMF 24.

[0124] When the crankshaft rotation speed variation ω exceeds the first variation determination threshold A1 (YES in S112), the degree of opening of the D throttle 12 is reduced (S114). In this way, the output variation of the engine 2 is reduced and the resonance is reduced or eliminated in the early stage of the occurrence of resonance of the DMF 24. When the crankshaft rotation speed variation ω exceeds the second variation determination threshold A2 (YES in S112, YES in S116, AND NO in S118), the degree of opening of the D throttle 12 is reduced (S114) and the amount of fuel supplied to the cylinders by fuel injection is reduced (S120). In this way, the reduction or elimination of resonance when the engine speed NE becomes closer to the resonant rotation speed of the DMF 24 than the first variation determination threshold A1 is, is performed.

[0125] When the crankshaft rotation speed variation ω exceeds the third variation determination threshold A3 (YES in S112, YES in S116, AND YES in S118), the degree of opening of the D throttle 12 is reduced (S114) and the fuel injection into the cylinders is stopped (S122). Thus, the engine speed NE is rapidly reduced by stopping the engine when the engine speed NE becomes closer to the resonant rotation speed of the DMF 24 than the second variation determination threshold A2 is. In this way, the resonance is reduced and eventually eliminated by causing the engine speed NE to quickly pass the resonance point.

[0126] As described above, the crankshaft rotation speed variation ω , that is, the magnitude of variation of the crankshaft rotation speed of the engine 2 is determined with the use of the variation determination thresholds A1 to A3. Because the crankshaft rotation speed variation ω that reflects the actual resonance state is the subject of determination instead of determining the occurrence of resonance with the use of the engine speed alone, the resonance state of the DMF 24 is accurately determined.

[0127] In addition, the variation determination thresholds A1 to A3 are set according to the braking operation state obtained by detecting the state of operation reflecting the intention of the vehicle's driver to accelerate or decelerate, which is the state of brake pedal depressing operation in this embodiment and includes whether or not the operation is

being performed (S102 to S108). Thus, appropriate variation determination thresholds A1 to A3 are set for the resonance not only when the vehicle's driver is actually performing the braking operation but also when no braking operation is being performed. Specifically, as shown in FIG. 5, during a braking operation, that is, when the vehicle's driver depresses the brake pedal in order to stop the vehicle, the engine 2 may be stopped early and therefore, the variation determination thresholds A1 to A3 are made small. During no braking operation, that is, when the driver does not depress the brake pedal, such as when the driver is starting the vehicle as shown in FIG. 4, it is desired to maximally retard the timing of stopping the engine 2 and therefore, the variation determination thresholds A1 to A3 are made large.

[0128] In this way, it is possible to detect the start of resonance of the DMF 24 accurately based on the information on the intention of the vehicle's driver to decelerate, the information including whether or not the operation is being performed. Thus, it is possible to reduce or eliminate the output variation that occurs in the engine 2, at an appropriate timing based on the information on the intention including whether or not the operation is being performed.

[0129] (ii) In order for the DMF resonance prevention process (FIG. 2) to effectively function, it is necessary that the precondition (S100) that the engine speed NE is lower than the reference rotation speed that is set lower than the engine-stall prevention determination rotation speed that is set to prevent engine stall and that is set higher than the resonant rotation speed of the DMF 24, is satisfied. Because the reference rotation speed is lower than the engine-stall prevention rotation speed as described above, throttling the intake air, reducing the fuel injection amount, and fuel cut are performed after the engine speed NE falls below the engine-stall prevention determination rotation speed. Thus, it is possible to solve the problem of occurrence of resonance of the DMF 24 without impairing the existing performance of preventing engine stall and in accordance with the change in the environment around the internal combustion engine.

(Second Embodiment)

[0130] In a second embodiment, the braking operation state and the accelerating operation state are detected via the brake switch and the accelerator operation amount sensor, and the variation determination thresholds A1 to A3 are set according to the accelerating state and the decelerating state. Thus, the process shown in FIG. 6 is performed as the DMF resonance prevention process. Other features are the same as the corresponding features of the first embodiment.

[0131] In the DMF resonance prevention process (FIG. 6), instead of S102 to S106, which are steps for setting the variation determination threshold correction coefficient K in FIG 2, the process from S202 to S210 is performed to set the variation determination threshold correction coefficient K. The process of the other steps S200, and S212 to S226 is the same as that of S100 and S108 to S122 shown in FIG. 2.

[0132] Next, the process from S202 to S210 for setting the variation determination threshold correction coefficient K is mainly described. When the precondition is satisfied (YES in S-200), it is determined whether the brake switch is on (S202). When the brake switch is off (NO in S202), it is determined that the intention of the vehicle's driver to accelerate or decelerate is the intention of no braking, which includes the intention of accelerating, and it is then determined whether the accelerator operation amount is greater than 0%, that is, whether the accelerator pedal is depressed, which indicates that the vehicle's driver is performing an accelerating operation (S204).

[0133] When accelerator operation amount > 0% (YES in S204), it is determined that the intention of the vehicle's driver to accelerate or decelerate is the intention of accelerating, and a first correction coefficient k11 is set as the variation determination threshold correction coefficient K (S206).

[0134] When accelerator operation amount = 0% (NO in S204), it is determined that the intention of the vehicle's driver to accelerate or decelerate is the intention of no accelerating, and a second correction coefficient k12 is set as the variation determination threshold correction coefficient K (S208).

[0135] When the brake switch is on (YES in S202), it is determined that the intention of the vehicle's driver is the intention of braking, and a third correction coefficient k13 is set as the variation determination threshold correction coefficient K (S210). The first to third correction coefficients k11 to k13 satisfy the following relation: first correction coefficient k11 > second correction coefficient k12 > third correction coefficient k13.

[0136] When the variation determination threshold correction coefficient K is set in S206, S208, or S210, the three variation determination thresholds A1, A2, and A3 are calculated as shown by the above Expressions 1 to 3 with the use of this variation determination threshold correction coefficient K (S212).

[0137] The process after S212 is similar to that described with the use of FIG. 2 of the first embodiment. In this way, when the brake switch is on, this state is provided with high priority and regardless of whether or not the accelerator pedal is depressed, the variation determination threshold correction coefficient K is set based on the fact that the brake switch is on (S210). When the brake switch is off, the variation determination threshold correction coefficient K is set according to whether or not the accelerator pedal is depressed (S206, S208).

[0138] Thus, as shown in FIG. 7, when the brake switch is turned on (t20), the variation determination threshold correction coefficient K is made small regardless of the accelerator operation amount. As a result, as shown in FIG. 7, when w becomes greater than A1 (t21), becomes greater than A2 (t22), and eventually becomes greater than A3 (t23), these timings t21 to t23 are relatively early.

[0139] As shown in FIG. 8, when the brake switch is off and the accelerator operation amount becomes greater than 0% (t30), the variation determination threshold correction coefficient K is made large. As a result, as shown in FIG. 8, when ω becomes greater than A1 (t31), becomes greater than A2 (t32), and eventually becomes greater than A3 (t33), these timings t31 to t33 are relatively retarded. In this way, stopping the engine 2 is maximally retarded within the range, in which the influence of resonance does not become significant, so that the vehicle is smoothly started. Specifically, the chance of increasing the engine speed NE is raised to cause the engine speed NE to get out of the resonant region to start the vehicle before ω eventually becomes greater than A3.

[0140] When the brake switch is off and the accelerator operation amount is 0%, the system is in the state before timing t30 of FIG. 8. In this case, the three variation determination thresholds A1, A2, and A3 are set with the use of the variation determination threshold correction coefficient K (= k12) that has a value intermediate between the variation determination threshold correction coefficient K (= k13) used when the brake switch is on and the variation determination threshold correction coefficient K (= k11) used when the brake switch is off and the accelerator operation amount is greater than 0%. Thus, the timings, at which ω becomes greater than A1, A2, and A3, also become intermediate.

[0141] In the above configuration, the ECU 30 functions as the means as described in the description of the first embodiment. The brake switch and the accelerator operation amount sensor function as the operation state detection means. The process of detecting the crankshaft rotation speed variation ω (FIG. 3) functions as the crankshaft rotation speed variation detection means. In the DMF resonance prevention process (FIG. 6), S202 to S212 function as the variation determination threshold setting means, S214, S216, S220, and S222 function as the resonance start determination means, and S200, S218, S224, and S226 function as the output variation control means.

[0142] According to the above-described second embodiment, the following effects are obtained. (i) When the brake switch is on, the variation determination threshold correction coefficient K is reduced as compared to the case where the brake switch is off (S210). In addition, when the brake switch is off and the accelerator operation amount is greater than 0%, the variation determination threshold correction coefficient K is increased as compared to the case where the brake switch is off and the accelerator operation amount is 0% (S206, S208). In this way, the variation determination thresholds A1 to A3 are set according to the braking and accelerating operation state obtained by detecting the state of operation reflecting the intention of the vehicle's driver to accelerate or decelerate, which is the state of brake pedal depressing operation and the state of accelerator pedal depressing operation in this embodiment and includes whether or not the operation is being performed (S202 to S212). Thus, appropriate variation determination thresholds A1 to A3 are set when the vehicle's driver is actually performing braking operation and/or accelerating operation. In addition, appropriate variation determination thresholds A1 to A3 are set not only in such a case but also for the resonance that occurs when these operations are not performed.

[0143] In this way, it is possible to detect the start of resonance of the DMF 24 accurately based on the information on the intention of the vehicle's driver to accelerate or decelerate, the information including whether or not the operation is being performed. Thus, it is possible to reduce or eliminate the output variation that occurs in the engine 2, at an appropriate timing based on such intention.

[0144] (ii) The effect (ii) of the first embodiment is also obtained.

(Third Embodiment)

[0145] In a third embodiment, instead of setting the variation determination threshold correction coefficient K (S106) when the brake switch is on in the first embodiment (YES in S102), the variation determination threshold correction coefficient K is determined based on a map MAPbp of FIG. 9.

[0146] The brake hydraulic pressure sensor is connected to the ECU 30 as one of other sensors and switches, for detection of the brake hydraulic pressure Pb. MAPbp is a map that sets the relation of the value of the variation determination threshold correction coefficient K with the brake hydraulic pressure Pb. This map is set so that the higher the brake hydraulic pressure Pb is, the smaller the variation determination threshold correction coefficient K is. Note that the brake pedal depression speed Vb may be used instead of using the brake hydraulic pressure Pb. For example, variation of the brake hydraulic pressure Pb with time may be used as the brake pedal depression speed Vb.

[0147] In this way, as described in FIG. 10, when the brake is applied (at and after t40), the variation determination thresholds A1 to A3 decrease as the brake hydraulic pressure Pb increases. Thus, as shown in FIG. 10, when ω becomes greater than A1 (t41), becomes greater than A2 (t42), and eventually becomes greater than A3 (t43), these timings t41 to t43 are advanced in proportion to the brake hydraulic pressure Pb and the brake pedal depression speed Vb, that is, the intensity of the braking operation.

[0148] In the above configuration, the brake switch and the brake hydraulic pressure sensor function as the operation state detection means. Other components function as described in the description of the first embodiment. Note that the third embodiment can be applied to the process (FIG. 6: S210) of setting the variation determination threshold correction coefficient K when the brake switch is on (FIG. 6: YES in S202) in the second embodiment.

[0149] According to the above-described third embodiment, the following effects are obtained. (i) The effects obtained

by the first embodiment are obtained. When the third embodiment is applied to the system of the second embodiment, the effects obtained by the second embodiment are obtained. In addition to such effects, it is possible to finely reflect the intention of the vehicle's driver on deceleration and it is possible to reduce or eliminate the output variation that occurs in the engine 2, at an appropriate timing based on the information on the intention including whether or not the operation is being performed.

(Fourth Embodiment)

[0150] In a fourth embodiment, instead of the process shown in FIG. 2 of the first embodiment, the DMF resonance prevention process shown in FIG. 11 is performed as interrupts at certain time intervals. Other features are the same as the corresponding features of the first embodiment and therefore, description will be made with reference to FIGS. 1 and 3.

[0151] When the DMF resonance prevention process (FIG. 11) is started, it is first determined whether the precondition is satisfied (S300). This step is the same as S100 of FIG. 2. When the precondition is not satisfied (NO in S300), the process is temporarily exited.

[0152] When the precondition is satisfied (YES in S300), the process of setting the variation determination threshold correction coefficient K is performed (S302). This process is the same as the process from S102 to S106 shown in FIG. 2 of the first embodiment. Alternatively, this process may be the process from S202 to S210 shown in FIG. 6 of the second embodiment. Alternatively, a map MAPbp as shown in FIG. 9 of the third embodiment may be used to set the variation determination threshold correction coefficient K.

[0153] When the variation determination threshold correction coefficient K is set in this way, two variation determination thresholds B1 and B2 are calculated with the use of the variation determination threshold correction coefficient K as shown by the Expressions 5 and 6 (S304).

[0154]

(Expression 5)

$$B1 \leftarrow b1 \times K$$

(Expression 6)

$$B2 \leftarrow b2 \times K$$

Variation determination threshold reference values b1, b2 are reference values for setting the two threshold values for determining at which level the crankshaft rotation speed variation ω is in the early stage of resonance. The variation determination threshold reference values b1, b2 are set according to the kind of the engine 2 and the driving system thereof in advance. Note that the first and second variation determination threshold reference values b1 and b2 are in the following relation: first variation determination threshold reference value b1 < second variation determination threshold reference value b2.

[0155] The above Expressions 5 and 6 set two levels of the variation determination thresholds B1 and B2 based on the operation state that reflects the intention of the vehicle's driver to accelerate or decelerate even when neither accelerating operation nor decelerating operation is being performed.

[0156] The detection value of the variation ω of the rotation speed of the crankshaft 2a is read into the working area provided in the RAM in the ECU 30 (S306). The detection value of the crankshaft rotation speed variation ω is the value that is detected by the process of detecting the crankshaft rotation speed variation ω (FIG. 3) described in the description of the first embodiment.

[0157] Next, it is determined whether the crankshaft rotation speed variation ω read in the current execution of S306 is greater than the first variation determination threshold B1 (S308). The first variation determination threshold B1 is the first threshold that indicates that the engine speed NE approaches the resonant rotation speed of the DMF 24. When $\omega \leq B1$ (NO in S308), it is determined that the crankshaft rotation speed variation ω is sufficiently small and there is no fear of resonance occurring in the DMF 24, and the process is temporarily exited.

[0158] When $\omega > B1$ (YES in S308), it is determined whether the crankshaft rotation speed variation ω is greater than the second variation determination threshold B2 (S310). The second variation determination threshold B2 is greater than the first variation determination threshold B1 and is the variation determination threshold that indicates that the

engine speed NE further approaches the resonant rotation speed of the DMF 24 than the first variation determination threshold B1 indicates. When $\omega \leq B2$ (NO in S310), the step of changing the frequency of the variation, with crank angle, of output generated by the engine 2 is performed (S312). Specifically, the frequency of the variation of output when the horizontal axis indicates crank angle values is changed.

[0159] When the engine 2 is a four-cylinder engine, as shown in FIG. 12A, the combustion stroke occurs every 180°CA and therefore, there are two output peaks per revolution of the crankshaft 2a. Thus, when NE = 180 rpm, for example, the output variation frequency along time axis is 6 Hz.

[0160] The output variation frequency changing process (S312) is a process that changes the state shown in FIG. 12A into one of the states shown in FIGS. 12B to 12D. In FIG. 12B, a process is performed, in which the output of the two cylinders (#1, #2) is increased by increasing the amount of fuel and the output of the other two cylinders (#3, #4) is accordingly reduced by reducing the amount of fuel. As a result of such increasing and reduction of the output, a set (#2, #1) of high-output combustion strokes occurs every 720°CA and therefore, an output peak occurs every two revolutions of the crankshaft 2a. Thus, when NE = 180 rpm, the output variation frequency along time axis is 1.5 Hz.

[0161] In FIG. 12C, the output of one cylinder (#1) is increased by increasing the amount of fuel and the output of the other three cylinders (#2, #3, #4) is accordingly reduced by reducing the amount of fuel. As a result of such increasing and reduction of the output, a high-output combustion stroke occurs every 720°CA and therefore, an output peak occurs per two revolutions of the crankshaft 2a. Thus, when NE = 180 rpm, the output variation frequency along time axis is 1.5 Hz.

[0162] In FIG. 12D, a combination of one cylinder with high output and two cylinders with accordingly low output is repeated. As a result of such increasing and reduction of the output, a high-output combustion stroke occurs every 540°CA and therefore, an output peak occurs every one and a half revolution of the crankshaft 2a. when NE = 180 rpm, the output variation frequency along time axis is 2 Hz.

[0163] As described above, when the fuel injection amount is the same for four cylinders as shown in FIG. 12A, the output variation frequency is 6 Hz when NE = 180 rpm. However, when the output of the combustion strokes of the respective cylinders is varied by changing the fuel injection amount between the cylinders as shown in FIGS. 12B to 12D, it is possible to immediately change the output variation frequency from 6 Hz to 1.5 Hz or 2 Hz.

[0164] The output variation frequency may be changed by retarding the fuel injection timing of the #1 cylinder and the #4 cylinder from the state shown in FIG. 13A to bring about high output at 360°CA intervals as shown in FIG. 13B, instead of changing the output between the cylinders as shown in FIGS. 12A to 12D.

[0165] Alternatively, the output variation frequency may be changed by advancing the fuel injection timing of the #2 cylinder and the #3 cylinder from the state shown in FIG. 13A to bring about high output at 360°CA intervals as shown in FIG. 13C or by retarding the fuel injection timing of the #1 cylinder and the #4 cylinder and advancing the fuel injection timing of the #2 cylinder and the #3 cylinder therefrom to bring about high output at 360°CA intervals as shown in FIG. 13D.

[0166] When the injection timings are brought closer in this way, a pair of high-output combustion strokes occurs every revolution of the crankshaft 2a. As a result, when NE = 180 rpm, the output variation frequency along time axis becomes 3 Hz and it is possible to quickly change the output variation frequency from 6 Hz shown in FIG. 13A.

[0167] In S312, the process of changing the frequency of the variation of output with crank angle is executed by performing one of or both of changing of the fuel injection amount between the cylinders and relative advancing/retarding of the fuel injection timing between the cylinders. By performing the changing process, it is possible to immediately change the frequency of variation of output along time axis without change in the engine speed NE. Then, the process is temporarily exited.

[0168] When $\omega > B2$ (YES in S310), the D throttle 12 is fully closed and fuel cut to stop the fuel injection from the fuel injection valve 4 is performed (S314). In this way, the engine 2 is brought toward stoppage and the engine speed NE quickly passes the resonance point. Thus, resonance of the DMF 24 does not become a problem.

[0169] When the determination in S300 or S308 is negative (NO), the changing of the fuel injection amount between the cylinders and the relative advancing and retarding of the fuel injection timing between the cylinders are not performed as shown in FIG. 12A and FIG. 13A.

[0170] In the above configuration, the ECU 30 functions as the means as described in the description of the first embodiment. The brake switch (in addition, the accelerator operation amount or the brake hydraulic pressure sensor, depending on the process of setting the variation determination threshold correction coefficient K as described above) functions as the operation state detection means. The process of detecting the crankshaft rotation speed variation ω (FIG. 3) functions as the crankshaft rotation speed variation detection means. In the DMF resonance prevention process (FIG. 11), S302 and S304 function as the variation determination threshold setting means; S306 to S310 function as the resonance start determination means; and S300, S312, and S314 function as the output variation control means.

[0171] According to the above-described fourth embodiment, the following effects are obtained. (i) It is possible to change the engine output variation frequency by the process from S306 to S312 of the DMF resonance prevention process (FIG. 11). When first variation determination threshold B1 < crankshaft rotation speed variation $\omega \leq$ second variation determination threshold B2 (YES in S308 AND NO in S310), it is possible to quickly change the frequency of variation of output along time axis without changing the engine speed NE. In this way, it is possible to bring the output

variation frequency apart from the resonance point of the DMF 24 to reduce or eliminate the resonance of the DMF 24.

[0172] When the crankshaft rotation speed variation ω exceeds the second variation determination threshold B2 (YES in S308 AND YES in S310), fully closing the D throttle 12 and fuel cut are performed (S314). Thus, when the engine speed NE becomes closer to the resonant rotation speed than the first variation determination threshold B1 is, the engine speed NE is rapidly reduced by stopping the engine 2 and caused to quickly pass the resonance point to eliminate the resonance in the end.

[0173] As described in the description of the first to third embodiments, the variation determination thresholds B1 and B2 are set based on the operation state that reflects the intention of the vehicle's driver to accelerate or decelerate even when neither accelerating operation nor decelerating operation is being performed. Thus, it is possible to reduce or eliminate the output variation by changing the output variation frequency or stopping the engine 2 at an appropriate timing in the early stage of the occurrence of resonance of the DMF 24.

[0174] (ii) The effect (ii) of the first embodiment is obtained.

(Fifth Embodiment)

[0175] In a fifth embodiment, instead of the process shown in FIG. 2 of the first embodiment, the DMF resonance prevention notification process shown in FIG. 14 is executed as interrupts at certain time intervals. Other features are the same as the corresponding features of the first embodiment and therefore, description will be made with reference to FIGS. 1 and 3.

[0176] When the DMF resonance prevention notification process (FIG. 14) is started, it is determined whether the precondition is satisfied (S400). The process is the same as that of S100 in FIG. 2. When the precondition is not satisfied (NO in S400), the process is temporarily exited.

[0177] When the precondition is satisfied (YES in S400), the process of setting the variation determination threshold correction coefficient K is performed (S402). This process is the same as the process from S102 to S106 shown in FIG. 2 of the first embodiment. Alternatively, this process may be the process from S202 to S210 shown in FIG. 6 of the second embodiment. Alternatively, a map MAPbp as shown in FIG 9 of the third embodiment may be used to set the variation determination threshold correction coefficient K.

[0178] When the variation determination threshold correction coefficient K is set in this way, the variation determination threshold C1 is calculated with the use of the variation determination threshold correction coefficient K as shown by the Expression 7 (S404).

(Expression 7)

$$C1 \leftarrow c1 \times K$$

The variation determination threshold reference value c1 is a reference value for setting the threshold for determining whether the crankshaft rotation speed variation ω is in the early stage of the occurrence of resonance. The variation determination threshold reference value c1 is set according to the kind of the engine 2 and the driving system thereof in advance.

[0179] The above Expression 7 sets the variation determination threshold C1 based on the operation state that reflects the intention of the vehicle's driver to accelerate or decelerate even when neither accelerating operation nor decelerating operation is being performed.

[0180] The detection value of the rotation speed variation ω of the crankshaft 2a is read into the working area provided in RAM in the ECU 30 (S406). The detection value of the crankshaft rotation speed variation. ω is the value that is detected by the process of detecting the crankshaft rotation speed variation ω (FIG. 3) described in the description of the first embodiment.

[0181] Next, it is determined whether the clutch switch, which corresponds to a clutch sensor, is off (S408). When the clutch switch is on, that is, when the clutch 26 is in an engagement state (NO in S408), the process is temporarily exited.

[0182] When the clutch switch is off, that is, when the clutch 26 is in an engagement state (YES in S408), it is determined whether the crankshaft rotation speed variation ω that has been read in the current execution of S406 is greater than the variation determination threshold C1 (S410). The variation determination threshold C1 is a variation determination threshold that indicates that the engine speed NE approaches the resonant rotation speed of the DMF 24. When $\omega \leq C1$ (NO in S410), it is determined that the crankshaft rotation speed variation ω is sufficiently small and there is no fear of resonance occurring in the DMF 24, and the process is temporarily exited.

[0183] When $\omega > C1$ (YES in S410), a notification of warning is output by displaying the request to disengage the clutch 26 on the display 36 (S412). In this embodiment, the warning lamp for requesting disengagement of the clutch,

which is provided on the display 36, is lit or turned on and off to request the vehicle's driver to disengage the clutch 26.

[0184] The timing chart of FIG. 15 shows an example of a process according to the fifth embodiment. Before timing t50, although the MT 28 is shifted to the first gear, the clutch 26 is disengaged and the engine speed NE is not reduced. When the driver performs an engaging operation of the clutch 26 to start the vehicle, the clutch switch is turned off (t50), the engine speed NE decreases and then, falls below the reference rotation speed (ω) at and after t51).

[0185] When the engine speed NE further approaches the resonance point of the DMF 24, the crankshaft rotation speed variation ω increases and ω becomes greater than C1 (t52). As a result, the warning lamp to request disengagement of the clutch is lit. Then, when the driver who recognized the lighting of the warning lamp disengages the clutch 26 (t53), the warning lamp is turned off, the engine speed NE increases, the crankshaft rotation speed variation ω is reduced, and ω becomes equal to or lower than C1 (at and after t54).

[0186] The variation determination threshold C1 is not constant and is set based on the operation state that reflects the intention of the vehicle's driver to accelerate or decelerate even when neither accelerating operation nor decelerating operation is being performed. Thus, it is possible to adapt the variation determination threshold C1 to the operation of the vehicle's driver to determine whether the engine speed NE approaches the resonance point of the DMF 24, at an appropriate timing.

[0187] As shown in the timing chart of FIG. 16, for example, when the brake switch is turned on (t61) after the clutch switch is turned off (at and after t60), the process of S402 and S404 is performed and the variation determination threshold C1 is reduced. Thus, the notification output is performed early (at and after t62). As a result, even when the vehicle's driver unintentionally engages the clutch 26 during a braking operation to stop the vehicle or when disengagement of the clutch 26 at the time of stopping the vehicle is late, it is possible to disengage the clutch early (t63) and it is thus possible to prevent resonance. During accelerating operation, the output of notification is delayed and it is possible to continue the accelerating operation without being annoyed by the output of notification.

[0188] In the above configuration, the ECU 30 functions as the crankshaft rotation speed variation detection means, the variation determination threshold setting means, and the resonance start determination means of the internal combustion engine resonance start detection system, and also functions as these means and the notification means of the internal combustion engine controller. The process of detecting the crankshaft rotation speed variation ω (FIG. 3) functions as the crankshaft rotation speed variation detection means. In the DMF resonance prevention notification process (FIG. 14), S402 and S404 function as the variation determination threshold setting means, S406 and S410 function as the resonance start determination means, and S400, S408, and S412 function as the notification means.

[0189] According to the above-described fifth embodiment, the following effects are obtained. (i) When the crankshaft rotation speed variation ω increases due to the engagement of the clutch 26, that is, when the engine speed NE decreases and approaches the resonance point of the DMF 24, by disengaging the clutch 26, it is possible to recover the engine speed NE to bring the engine speed NE apart from the resonance point of the DMF 24. Thus, when the crankshaft rotation speed variation ω exceeds the variation determination threshold C1 (YES in S410), the clutch disengagement warning notification is performed (S412). In this way, when the engine speed NE approaches the resonance rotation speed of the DMF 24, the vehicle's driver can immediately disengage the clutch 26.

[0190] The variation determination threshold C1 is set based on the operation state that reflects the intention of the vehicle's driver to accelerate or decelerate even when neither accelerating operation nor decelerating operation is being performed. Thus, it is possible to provide notification of the start of resonance at an appropriate timing based on the operational intention.

[0191] When the vehicle's driver disengages the clutch 26 late during the braking operation to stop the vehicle or when the vehicle's driver unintentionally engages the clutch 26 that was once disengaged, for example, the warning to disengage the clutch is issued early. Thus, if the vehicle's driver disengages the clutch 26, the engine speed NE is prevented from being reduced into the resonance region.

[0192] During accelerating operation, the issuance of warning is delayed and it is therefore possible to prevent the engine speed NE from being reduced into the resonance region by continuing the accelerating operation without being annoyed by the warning even when the clutch 26 is engaged.

[0193] Thus, the vehicle's driver can appropriately reduce or eliminate the variation of output generated by the engine 2, based on the request to disengage the clutch 26.

(Sixth Embodiment)

[0194] In a sixth embodiment, instead of the DMF resonance prevention notification process shown in FIG. 14 of the fifth embodiment, the DMF resonance prevention process shown in FIG. 17 is executed as interrupts at certain time intervals. Other features are the same as the corresponding features of the fifth embodiment and therefore, description will be made with reference to FIGS. 1 and 3.

[0195] The process from S500 to S512 of the DMF resonance prevention process (FIG. 17) is the same as the process from S400 to S412 in FIG. 14. The difference is that when $\omega > C1$ (YES in S510), the fuel injection amount increasing

step (S514) is performed along with the clutch disengagement warning notification (S512) as described above.

[0196] The fuel injection amount increasing step (S514) is a process of raising the engine speed NE that was about to drop due to the engagement of the clutch 26, by increasing the output of the engine 2 even before the clutch 26 is disengaged. In this way, the notification of the request to disengage the clutch to the vehicle's driver is provided and at the same time, the engine speed NE is actively brought apart from the resonance point of the DMF 24.

[0197] In the above configuration, the ECU 30 functions as the crankshaft rotation speed variation detection means, the variation determination threshold setting means, and the resonance start determination means of the internal combustion engine resonance start detection system, and also functions as these means, the notification means and the internal combustion engine output increasing means of the internal combustion engine controller. The process of detecting the crankshaft rotation speed variation ω (FIG. 3) functions as the crankshaft rotation speed variation detection means. In the DMF resonance prevention notification process (FIG. 17), S502 and S504 function as the variation determination threshold setting means, S506 and S510 function as the resonance start determination means, S500, S508, and S512 function as the notification means, and S500, S510, and S514 function as the internal combustion engine output increasing means.

[0198] According to the above-described sixth embodiment, the following effects are obtained. (i) In addition to the effects obtained by the fifth embodiment, the engine speed NE is raised by increasing the amount of fuel injection when the engine speed NE approaches the resonance point of the DMF 24. Thus, even before the vehicle's driver disengages the clutch 26, it is possible to quickly bring the engine speed NE apart from the resonance point of the DMF 24.

(Other Embodiments)

[0199] (a) In the above embodiments, setting the variation determination threshold with the use of the variation determination threshold correction coefficient K is performed in consideration of the decelerating operation or both of the decelerating operation and the accelerating operation. However, the variation determination threshold may be increased by increasing the variation determination threshold correction coefficient K during acceleration as compared to that during no-acceleration in consideration of the accelerating operation only.

[0200] (b) The precondition (S100, S200, S300, S400, S500) illustrated in the above embodiments is the logical "OR" condition that the engine speed NE is lower than the reference rotation speed OR the vehicle speed is lower than the reference vehicle speed. It has also been described that alternatively, the precondition may be that the engine speed NE detected by the crankshaft rotation speed sensor 32 is lower than the reference rotation speed, alone, or the precondition may be a logical "AND" condition that the engine speed NE is lower than a reference rotation speed AND the vehicle speed is lower than the reference vehicle speed.

[0201] In addition to such conditions, the condition, "the vehicle speed is lower than the reference vehicle speed or the engine speed NE is lower than the reference rotation speed corresponding to the reference vehicle speed AND the clutch is engaged," and the condition, "the vehicle is climbing a slope" may be added to the logical "OR" condition. Then, when one of these conditions is satisfied, the determination concerning the precondition (S100, S200, S300, S400, S500) is affirmative (YES).

[0202] In particular, when the condition, "the vehicle speed is lower than the reference vehicle speed or the engine speed NE is lower than the reference rotation speed corresponding to the reference vehicle speed AND the clutch is engaged," is added as one of the conditions of the logical "OR" condition in the first to fourth embodiments, it becomes possible to detect the reduction in rotation speed when the clutch is engaged at the time of starting the vehicle and it is therefore possible to accurately detect the start of resonance of the DMF 24 at the time of starting the vehicle.

[0203] When the condition, "the vehicle is climbing a slope," is added as one of the conditions of the logical "OR" condition, it is possible to detect the reduction in rotation speed at the time of climbing a slope and it is therefore possible to accurately detect the start of resonance of the DMF 24 during climbing a slope. (c) In the fifth and sixth embodiments, instead of the clutch switch, the clutch stroke sensor may be provided and the partial clutch engagement may be detected in addition to the engagement of the clutch 26. In this case, in S408 of the DMF resonance prevention notification process (FIG. 14) and S508 of the DMF resonance prevention process (FIG. 17), the determination is affirmative (YES) when the clutch 26 is in an engagement state or in a partial engagement state.

[0204] (d) In the case of the process of detecting the crankshaft rotation speed variation ω (FIG. 3), because the peak value of the rotational acceleration of the crankshaft varies with the magnitude of the rotation speed variation, instead of directly detecting the amplitude of the crankshaft rotation speed oscillation, the peak value of the rotational acceleration of the crankshaft 2a is detected. Actually, the peak value of the range of variation of the time taken for the crankshaft to rotate a certain angle is detected, which is assumed to correspond to the peak value of the rotational acceleration. The rotational acceleration itself may be detected and the peak value thereof may be directly used.

[0205] Alternatively, the peak value of the rotation speed variation may be detected and the amplitude of oscillation of the rotation speed of the crankshaft may be calculated based on the height of the peak value with respect to the average rotation speed and may be used as the magnitude of the crankshaft rotation speed variation.

[0206] The variation of the rotation speed of the crankshaft also corresponds to the variation of the amount of work performed by the crankshaft and therefore, in the process of detecting the crankshaft rotation speed variation ω , the variation of the amount of work performed by the crankshaft may be calculated to obtain the peak of the variation of the amount of work instead of the crankshaft rotation speed variation ω . Thus, in the DMF resonance prevention process (FIGS. 2, 6, 11, and 16) and the DMF resonance prevention notification process (FIG. 14), the determination is made with the use of the peak value of the variation of the amount of work. The value obtained by squaring the variation with time $\Delta\theta$ of the crankshaft rotation speed θ corresponds to the amount of work and therefore, the determination concerning the resonance may be made with the use of the square of $\Delta\theta$. The rotation speed θ or the time variation $\Delta\theta$ can be calculated from the pulse time interval T or the time interval variation dT.

[0207] (e) In the above-described embodiments, the invention is applied to a diesel engine. However, the invention may be applied to a gasoline engine, which is another internal combustion engine. (f) In the above-described first to fourth embodiments, a plurality of variation determination thresholds are set and the processes corresponding to these variation determination thresholds are performed when the crankshaft rotation speed variation ω exceeds these variation determination thresholds. However, a configuration may be employed in which the determination concerning the crankshaft rotation speed variation ω is made without using part of the variation determination thresholds and with the use of other part of the variation determination thresholds, to perform the corresponding process(es).

[0208] (g) In the above-described embodiments, the variation determination thresholds are calculated after the variation determination threshold correction coefficient K is set according to the operation state of the vehicle's driver. However, the variation determination threshold may be directly calculated based on the state of operation performed by the vehicle's driver.

Claims

1. An internal combustion engine resonance start detection system for detecting a start of resonance in an internal combustion engine (2), from which output is transmitted to a driving system of a vehicle via a dual mass flywheel (24), the internal combustion engine resonance start detection system being **characterized by** comprising:

crankshaft rotation speed variation detection means (30) for detecting a magnitude (ω) of variation of a crankshaft rotation speed of the internal combustion engine (2);
operation state detection means for detecting an operation state that reflects an intention of a driver of the vehicle to accelerate or decelerate and includes whether or not an operation is being performed;
variation determination threshold setting means (30) for setting a variation determination threshold (A1, A2, A3; B1, B2; C1) according to the operation state detected by the operation state detection means; and
resonance start determination means that determines that the start of resonance is detected, provided that the magnitude (ω) of variation detected by the crankshaft rotation speed variation detection means becomes greater than the variation determination threshold (A1, A2, A3; B1, B2; C1) that is set by the variation determination threshold setting means.

2. The internal combustion engine resonance start detection system according to claim 1, wherein the operation state detection means is configured to detect a braking operation state that includes whether a braking operation is being performed
and/or
is configured to detect an accelerating operation state that includes whether an accelerating operation is being performed.

3. The internal combustion engine resonance start detection system according to claim 2, wherein the operation state detection means is configured to detect said braking operation state and said accelerating operation state, and wherein, when the operation state detection means detects both the accelerating operation state that indicates that the accelerating operation is being performed and the braking operation state that indicates that the braking operation is being performed at the same time, the variation determination threshold setting means sets the variation determination threshold based on the braking operation state rather than the accelerating operation state.

4. An internal combustion engine controller for an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the internal combustion engine controller being **characterized by** comprising:

the internal combustion engine resonance start detection system according to any one of claims 1 to 3; and

output variation control means (30) for reducing or eliminating variation of output generated by the internal combustion engine when the resonance start determination means of the internal combustion engine resonance start detection system determines that the start of resonance is detected.

- 5 **5.** The internal combustion engine controller according to claim 4, wherein the output variation control means reduces the variation of output generated by the internal combustion engine by reducing an amount of intake air of the internal combustion engine,
and preferably wherein the internal combustion engine is a diesel engine having a throttle valve; and the output variation control means reduces the amount of intake air of the internal combustion engine by reducing a degree of opening of the throttle valve.
- 10 **6.** The internal combustion engine controller according to claim 4, wherein the output variation control means reduces the variation of output generated by the internal combustion engine by reducing an amount of fuel supply in the internal combustion engine,
15 or
wherein the output variation control means reduces or eliminates the variation of output generated by the internal combustion engine by stopping fuel supply in the internal combustion engine,
or
20 wherein the output variation control means reduces or eliminates the variation of output generated by the internal combustion engine by performing two of or all of a process of reducing the amount of intake air of the internal combustion engine, a process of reducing the amount of fuel supply in the internal combustion engine, and a process of stopping the fuel supply in the internal combustion engine.
- 25 **7.** The internal combustion engine controller according to claim 6, wherein:
the internal combustion engine is a diesel engine; and
the fuel supply is fuel injection into a combustion chamber performed by a fuel injection valve.
- 30 **8.** An internal combustion engine controller for an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the internal combustion engine controller being **characterized by** comprising:
the internal combustion engine resonance start detection system according to any one of claims 1 to 3; and
35 output variation control means (30) for changing a frequency of the variation, with crank angle, of output generated by the internal combustion engine when the resonance start determination means of the internal combustion engine resonance start detection system determines that the start of resonance is detected,
and preferably wherein:
40 the internal combustion engine includes a plurality of cylinders; the fuel supply into a combustion chamber of each of the cylinders is performed by fuel injection into the combustion chamber; and the output variation control means changes a frequency of the variation, with crank angle, of output generated by the internal combustion engine by causing one of or both of a difference in fuel injection timing between the cylinders and a difference in fuel injection amount between the cylinders.
- 45 **9.** The internal combustion engine controller according to any one of claims 4 to 8, the internal combustion engine controller further comprising:
rotation speed detection means (32) for detecting an engine speed of the internal combustion engine,
50 wherein: a reference rotation speed is set lower than an engine-stall prevention determination rotation speed set to prevent engine stall and higher than a resonant rotation speed of the dual mass flywheel; and
the output variation control means acts when the engine speed detected by the rotation speed detection means is lower than the reference rotation speed.
- 55 **10.** The internal combustion engine controller according to any one of claims 4 to 8, wherein the output variation control means acts when the vehicle is in a braking operation.

11. The internal combustion engine controller according to any one of claims 4 to 8, wherein the output variation control means acts when at least one of a condition that a vehicle speed is equal to or lower than a reference vehicle speed and a condition that the engine speed is equal to or lower than the reference rotation speed is satisfied and a clutch is in an engagement state or in a partial engagement state,

or

the internal combustion engine controller according to any one of claims 4 to 8, wherein the output variation control means acts when the vehicle is climbing a slope.

12. An internal combustion engine controller for an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the internal combustion engine controller being **characterized by** comprising:

a clutch sensor that detects an engagement state of a clutch that is disposed between the dual mass flywheel and the driving system;

the internal combustion engine resonance start detection system according to any one of claims 1 to 3; and notification means (30) that outputs notification to request disengagement of the clutch when the clutch sensor detects continuation of the engagement state or the partial engagement state of the clutch and the resonance start determination means of the internal combustion engine resonance start detection system determines that the start of resonance is detected,

and preferably wherein the notification means outputs the notification by lighting a warning lamp.

13. The internal combustion engine controller according to claim 12, wherein the notification means acts when an engine speed of the internal combustion engine is equal to or lower than a reference rotation speed.

14. The internal combustion engine controller according to claim 12 or 13, further comprising:

rotation speed detection means (32) for detecting an engine speed of the internal combustion engine; and internal combustion engine output increasing means (30) that increases the output from the internal combustion engine when the engine speed detected by the rotation speed detection means is lower than a reference rotation speed when the notification means outputs the notification.

15. An internal combustion engine resonance start detection method of detecting a start of resonance in an internal combustion engine, from which output is transmitted to a driving system of a vehicle via a dual mass flywheel, the internal combustion engine resonance start detection method being **characterized by** comprising:

detecting a magnitude of variation of a crankshaft rotation speed of the internal combustion engine (S 152 to S 166);

detecting an operation state that reflects an intention of a driver of the vehicle to accelerate or decelerate and includes whether or not an operation is being performed;

setting a variation determination threshold according to the detected operation state (S102 to S108; S202 to S212; S302, S304; S402, S404; S502, S504); and

determining that the start of resonance is detected, provided that the detected magnitude of variation becomes greater than the set variation determination threshold (S110, S112, S116, S118; S214, S216, S220, S222; S306 to S310; S406, S410; S506, S510).

FIG. 1

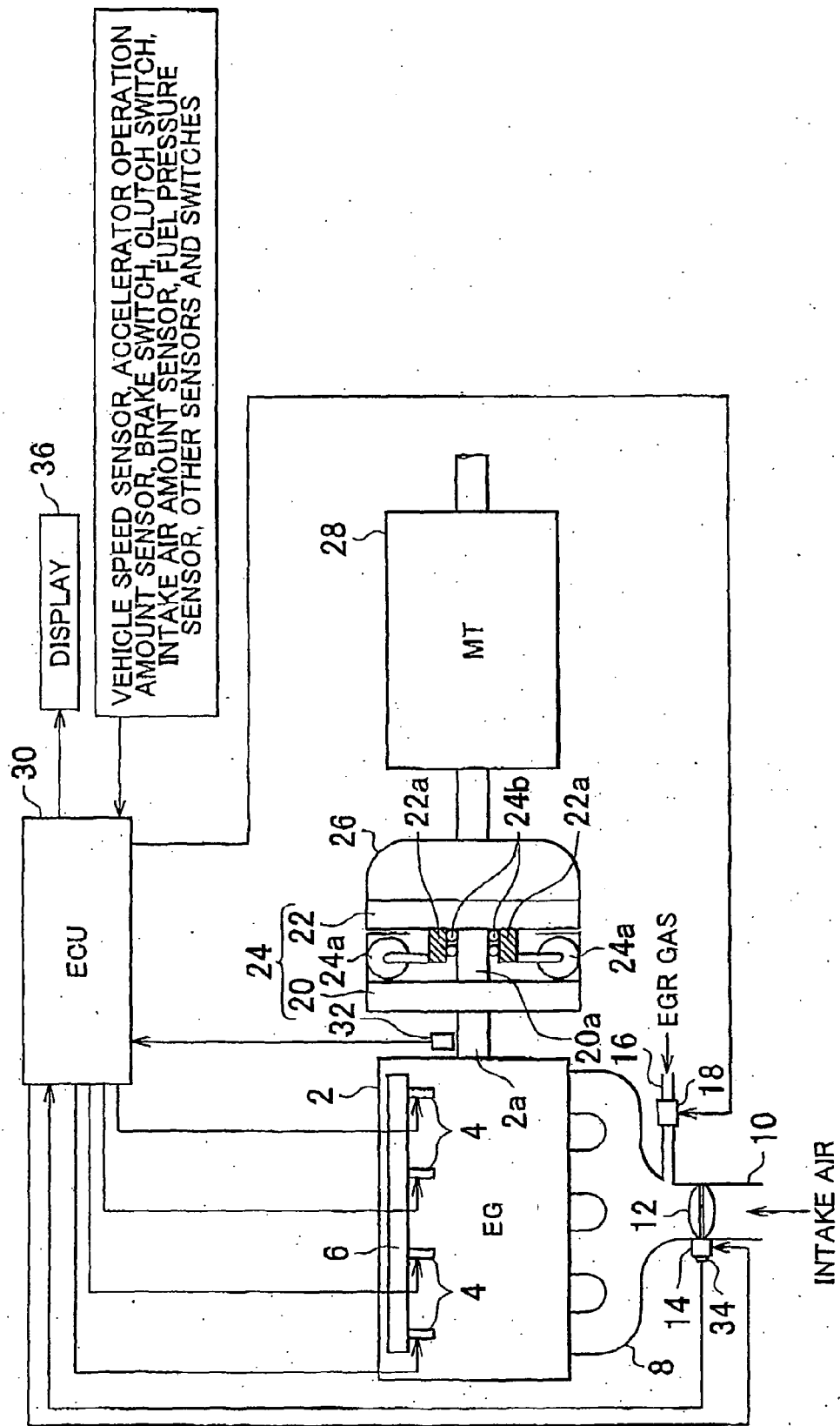


FIG. 2

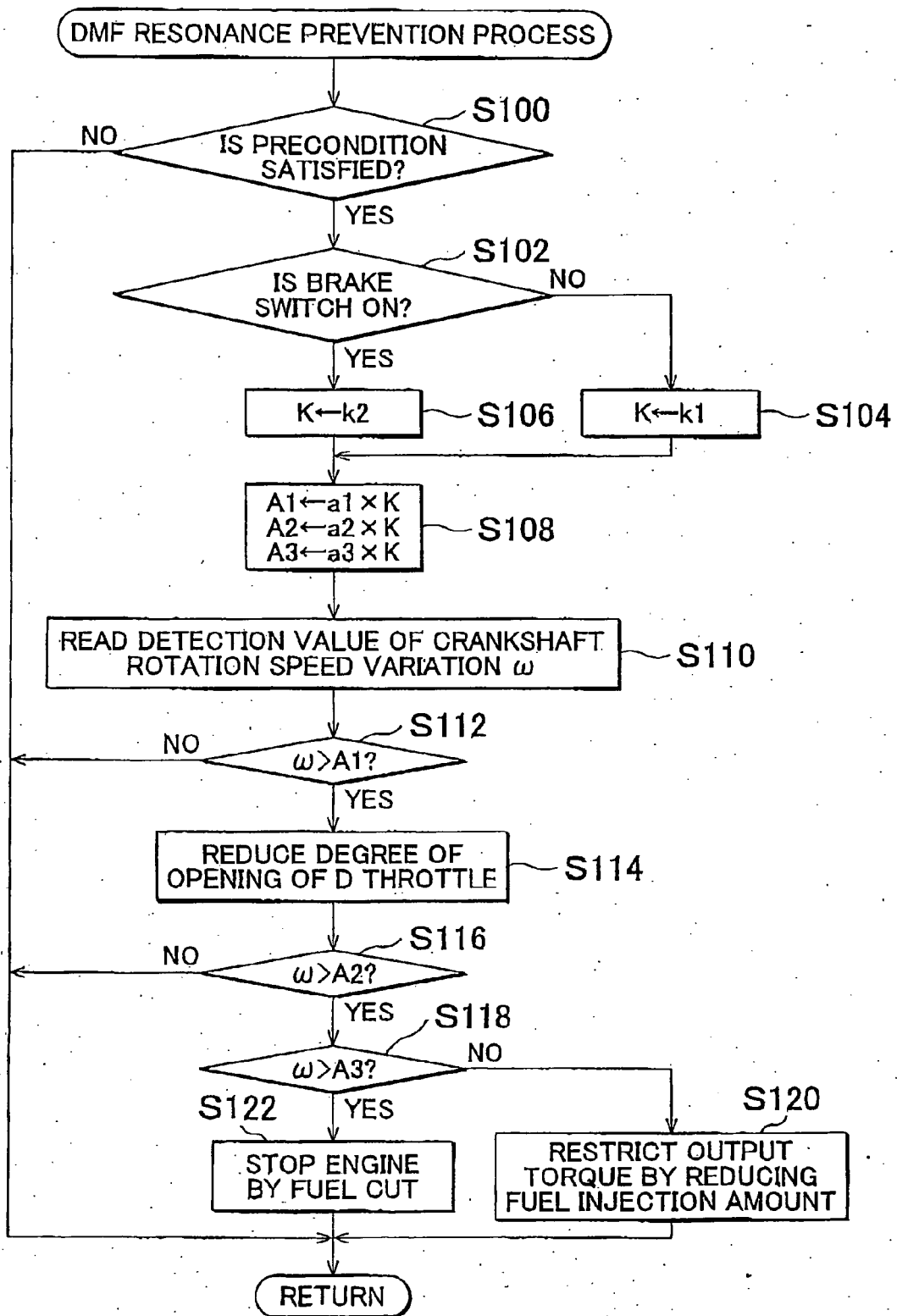


FIG. 3

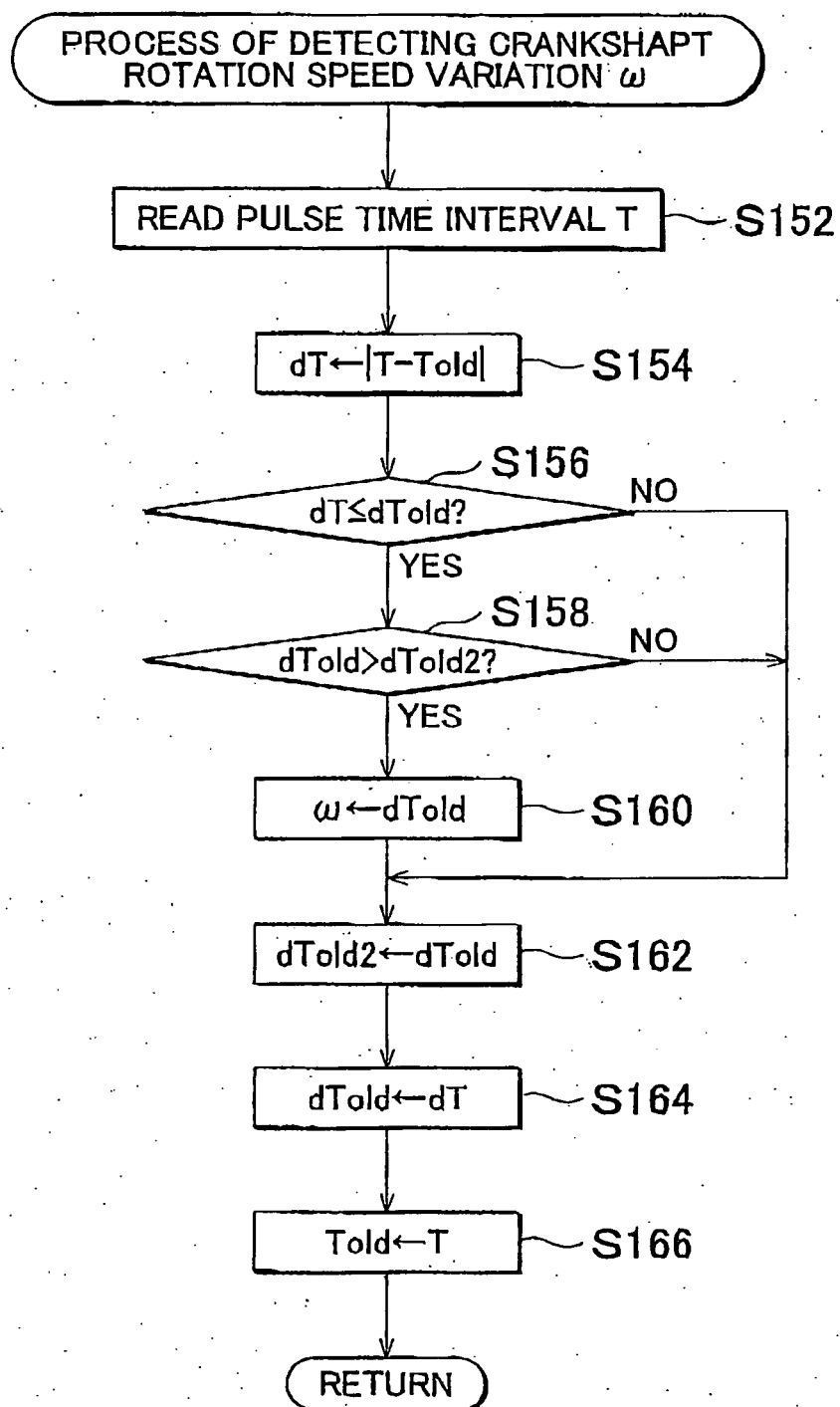


FIG. 4

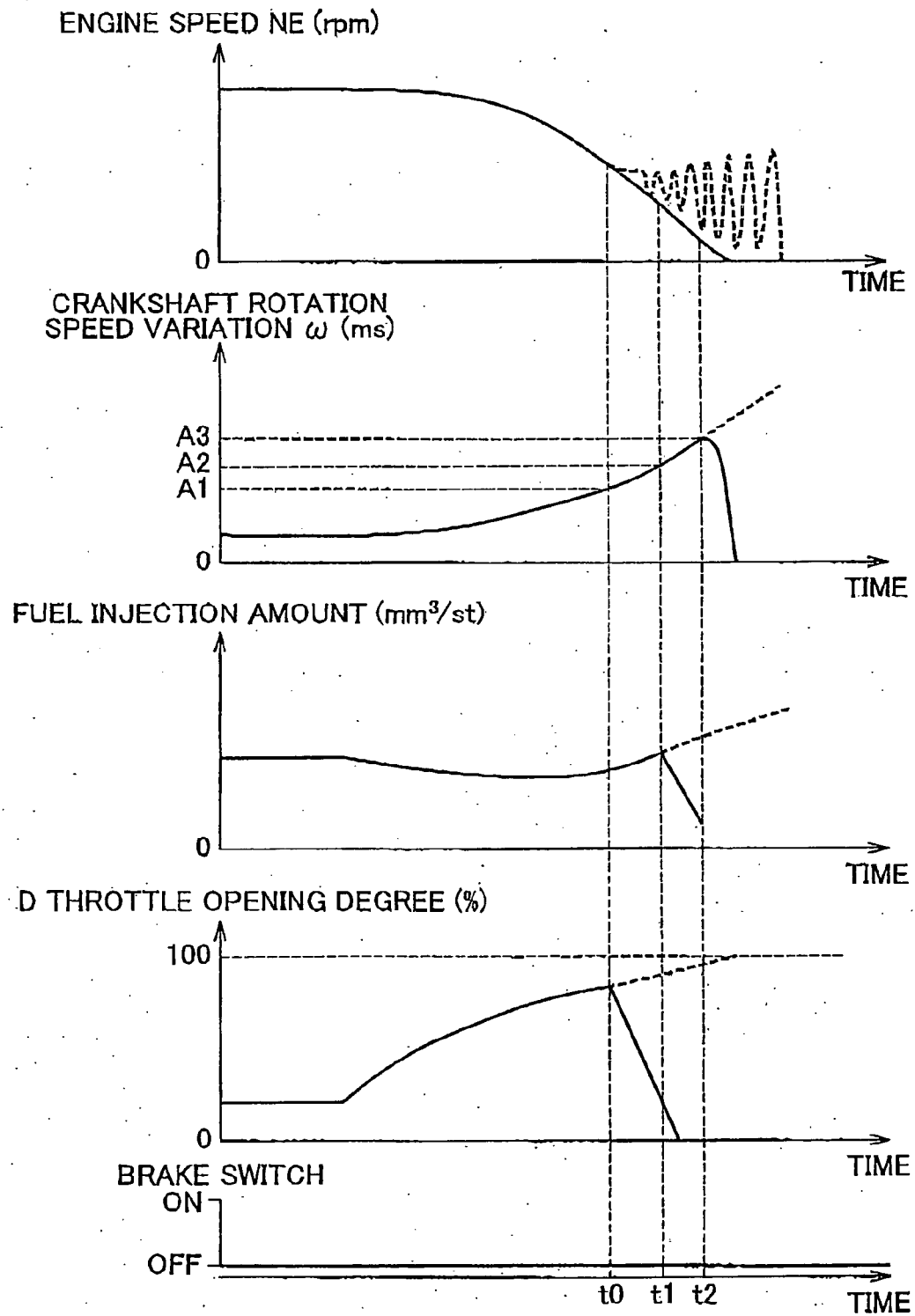


FIG. 5

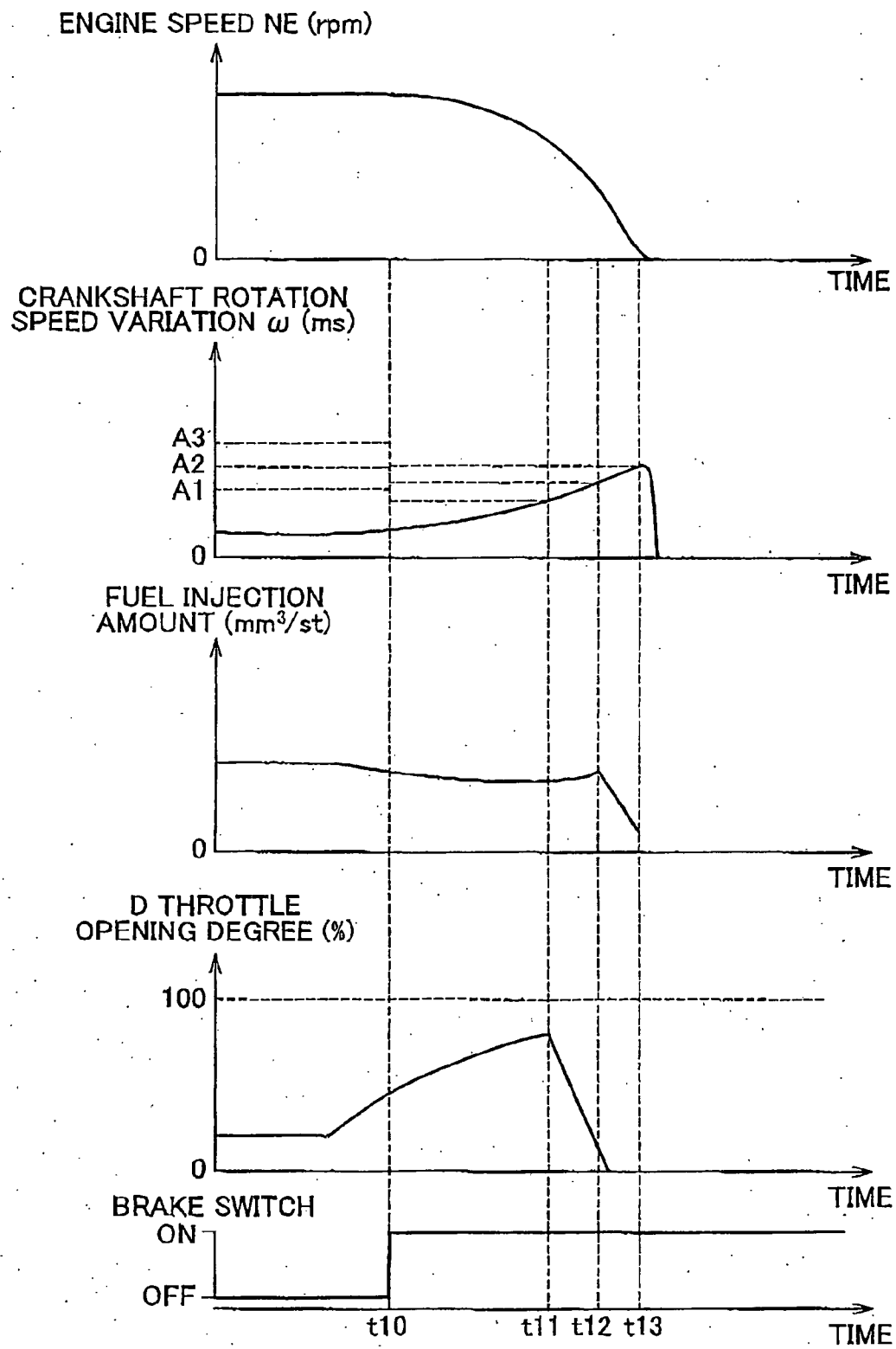


FIG. 6

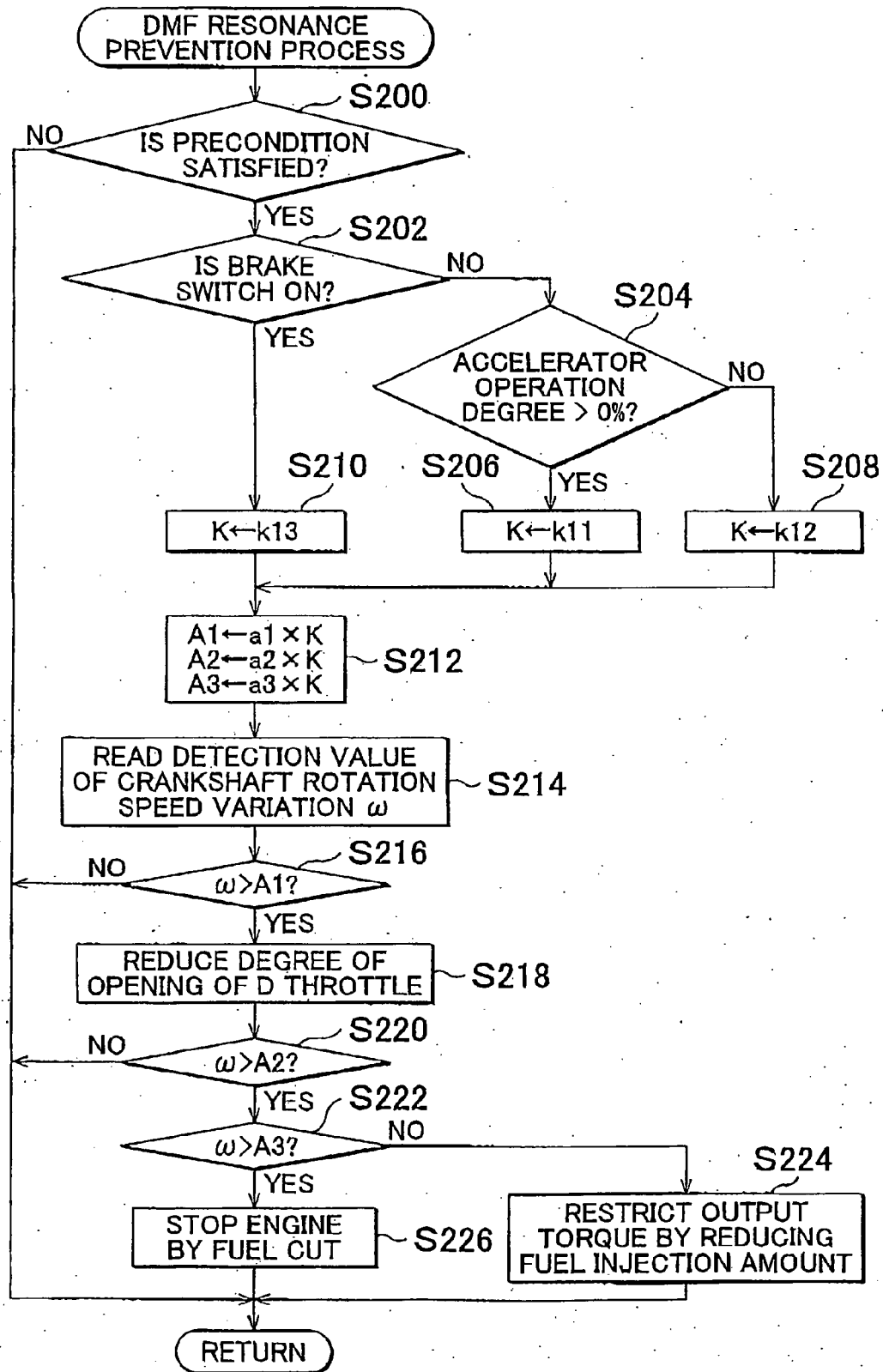


FIG. 7

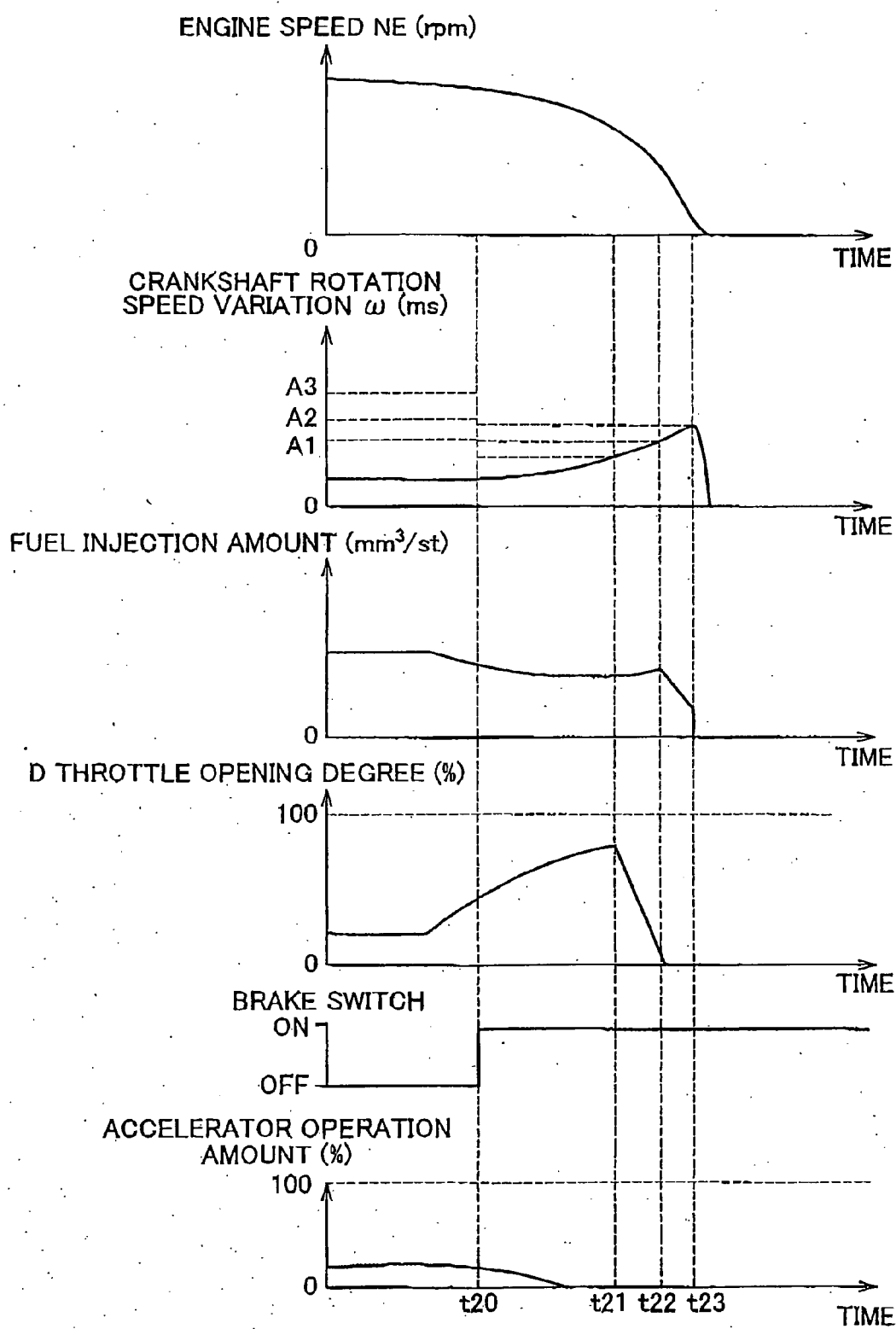


FIG. 8

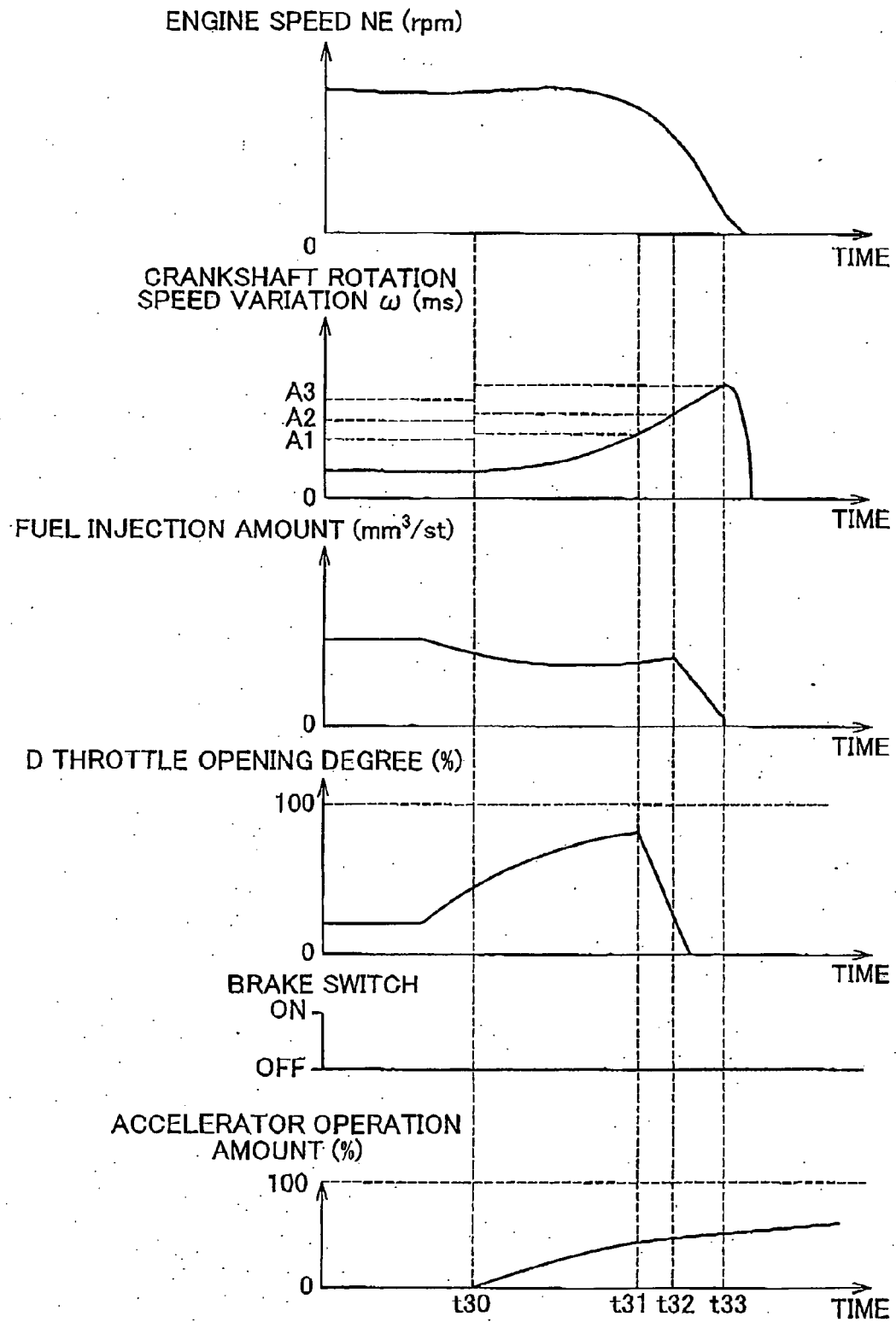


FIG. 9

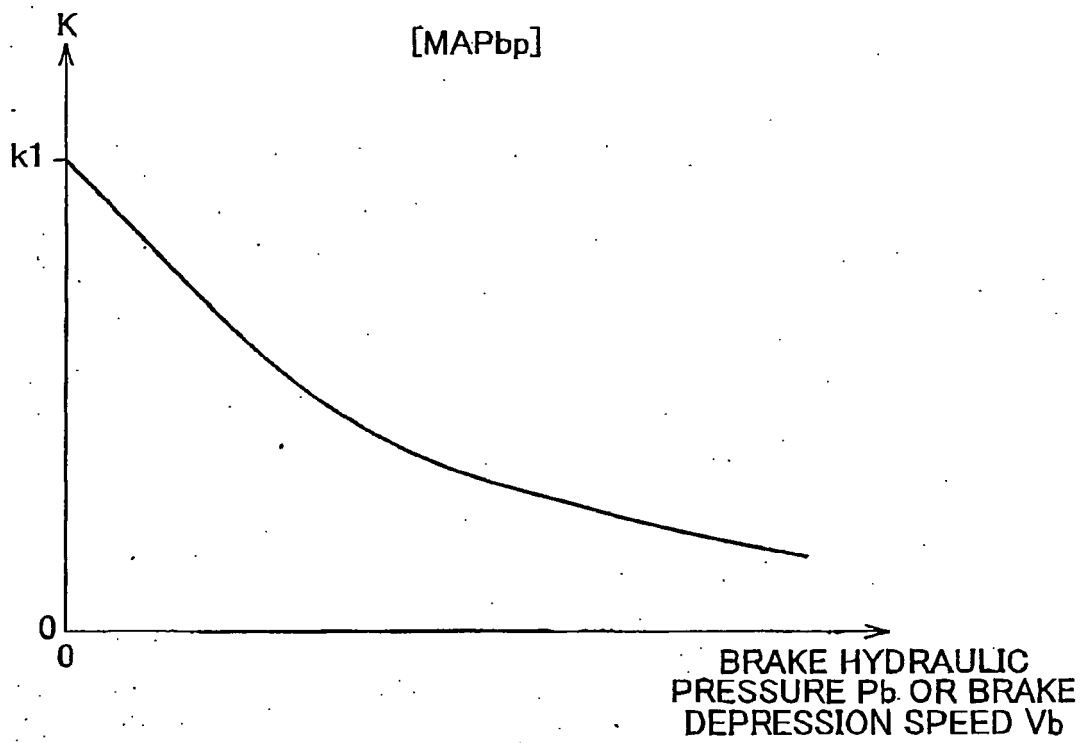


FIG. 10

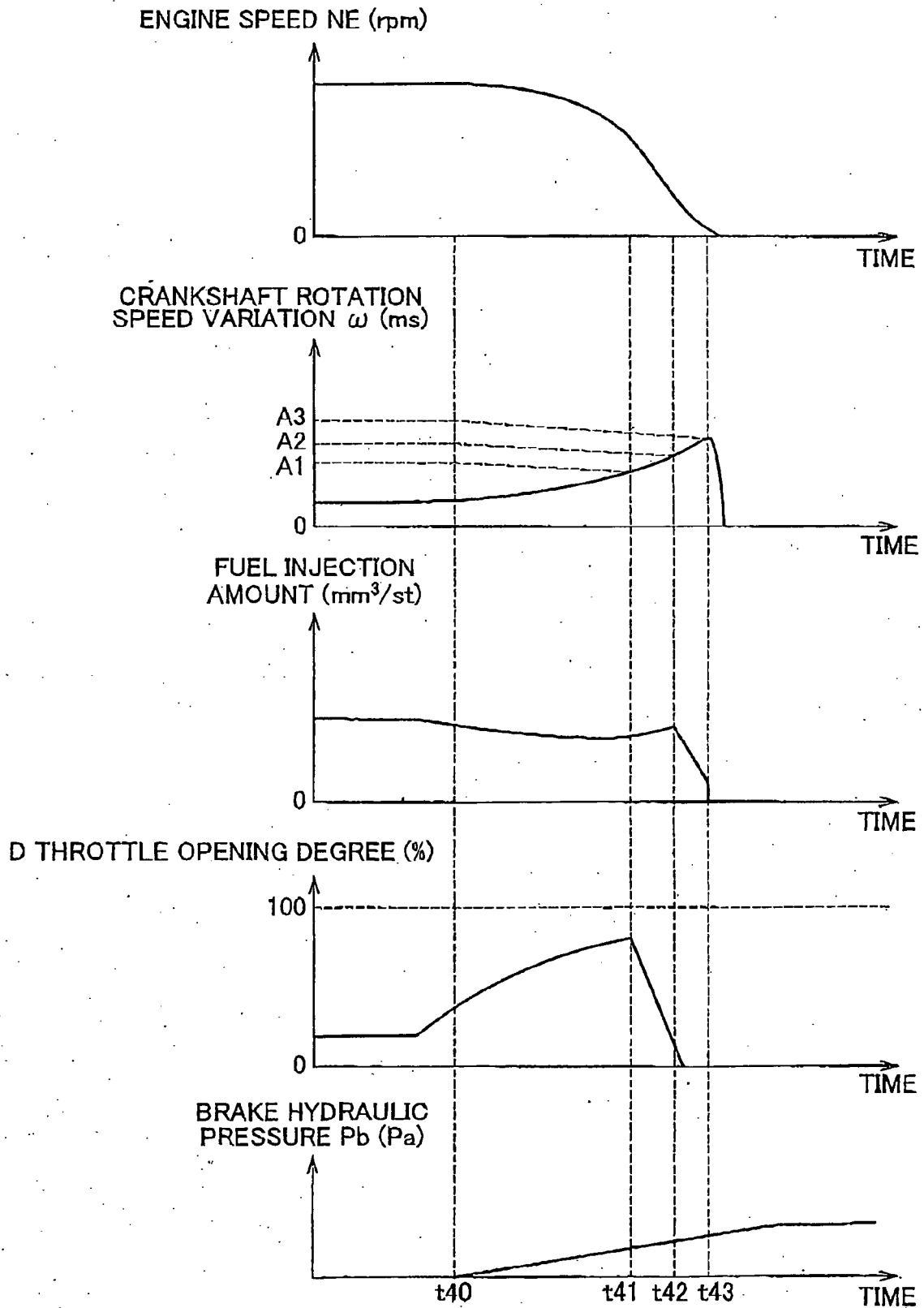


FIG. 11

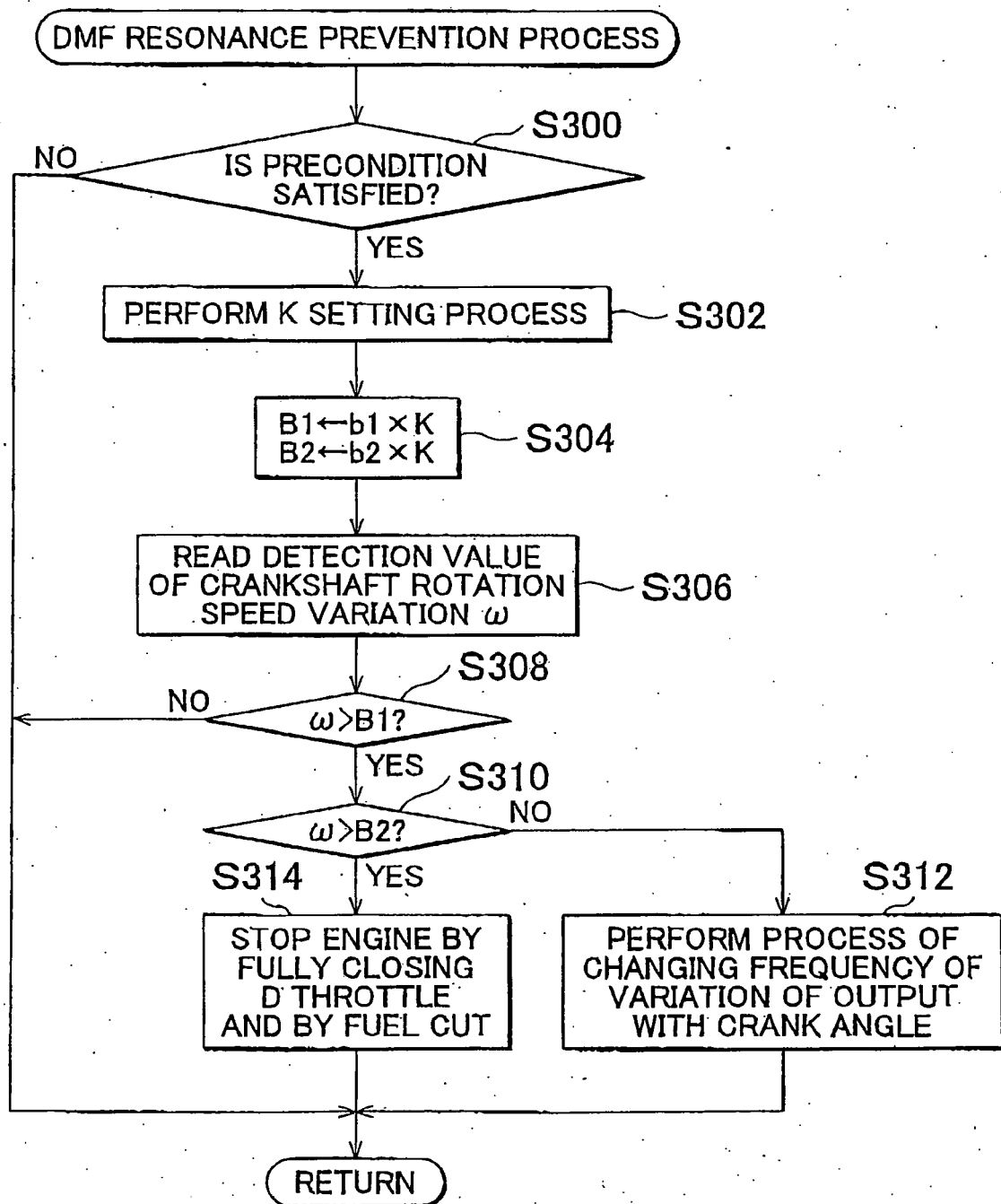


FIG. 12A

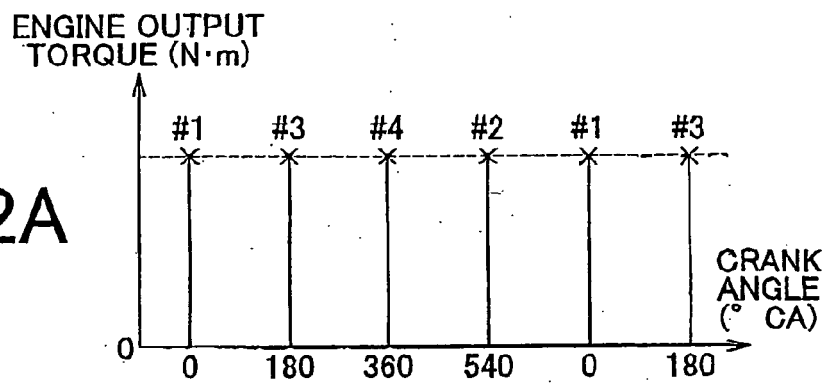


FIG. 12B

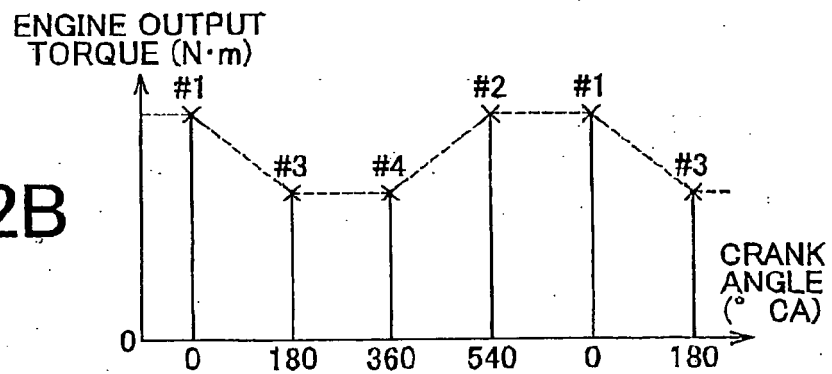


FIG. 12C

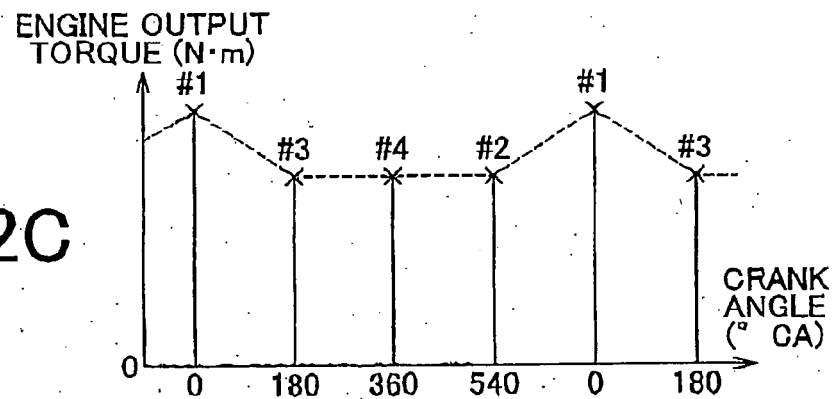


FIG. 12D

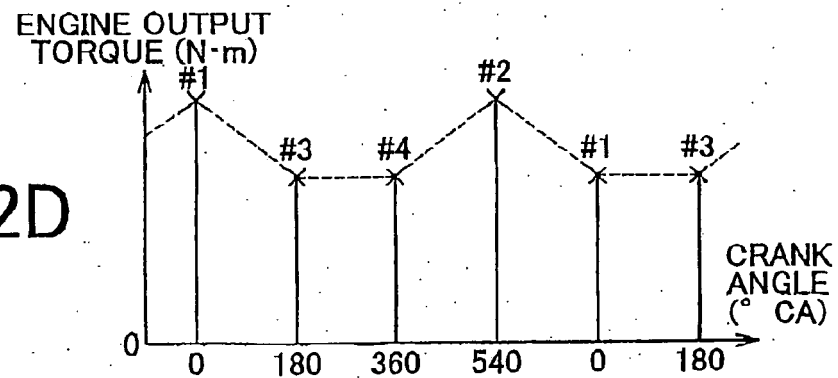


FIG. 13A

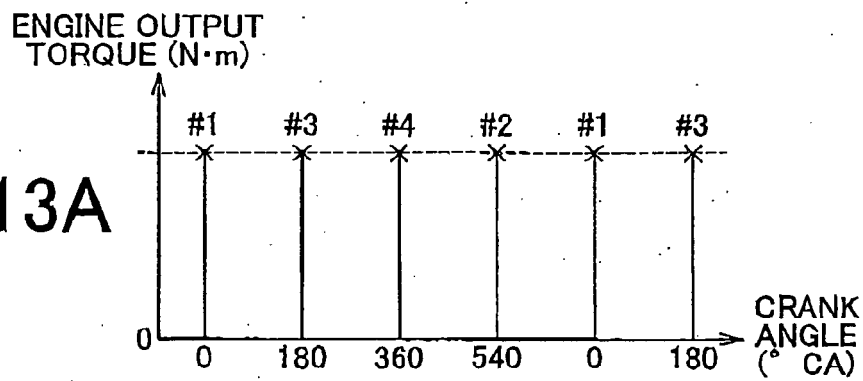


FIG. 13B

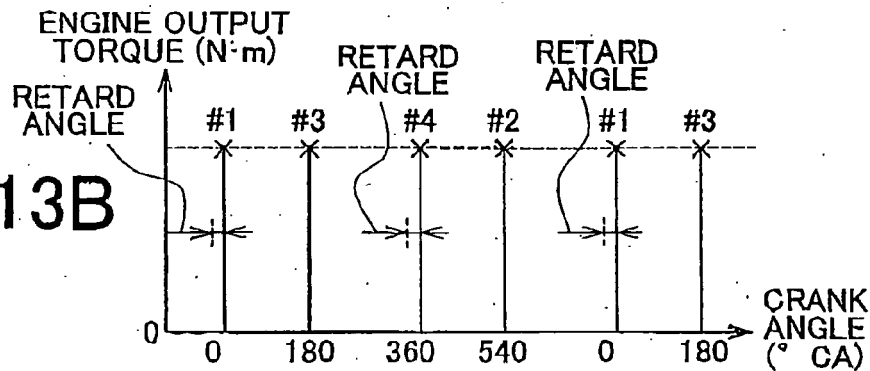


FIG. 13C

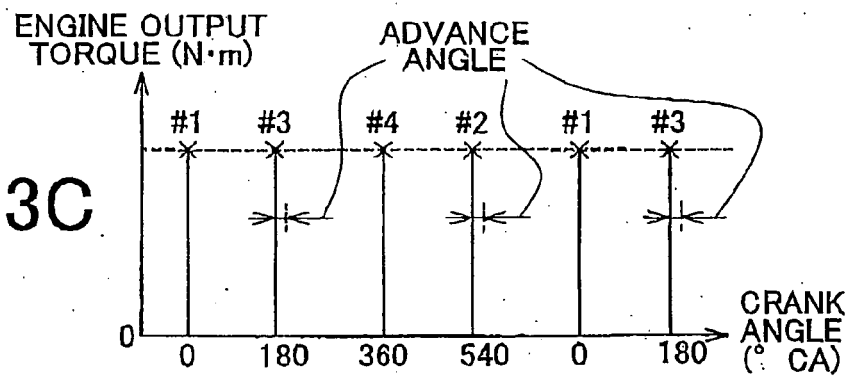


FIG. 13D

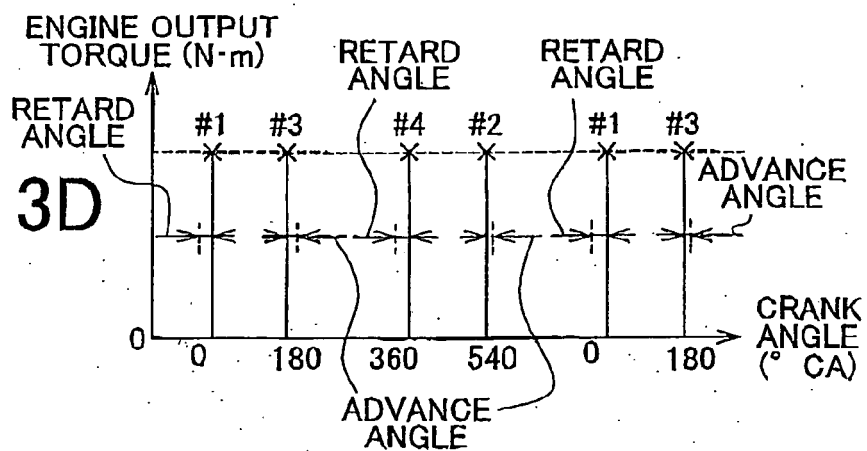


FIG. 14

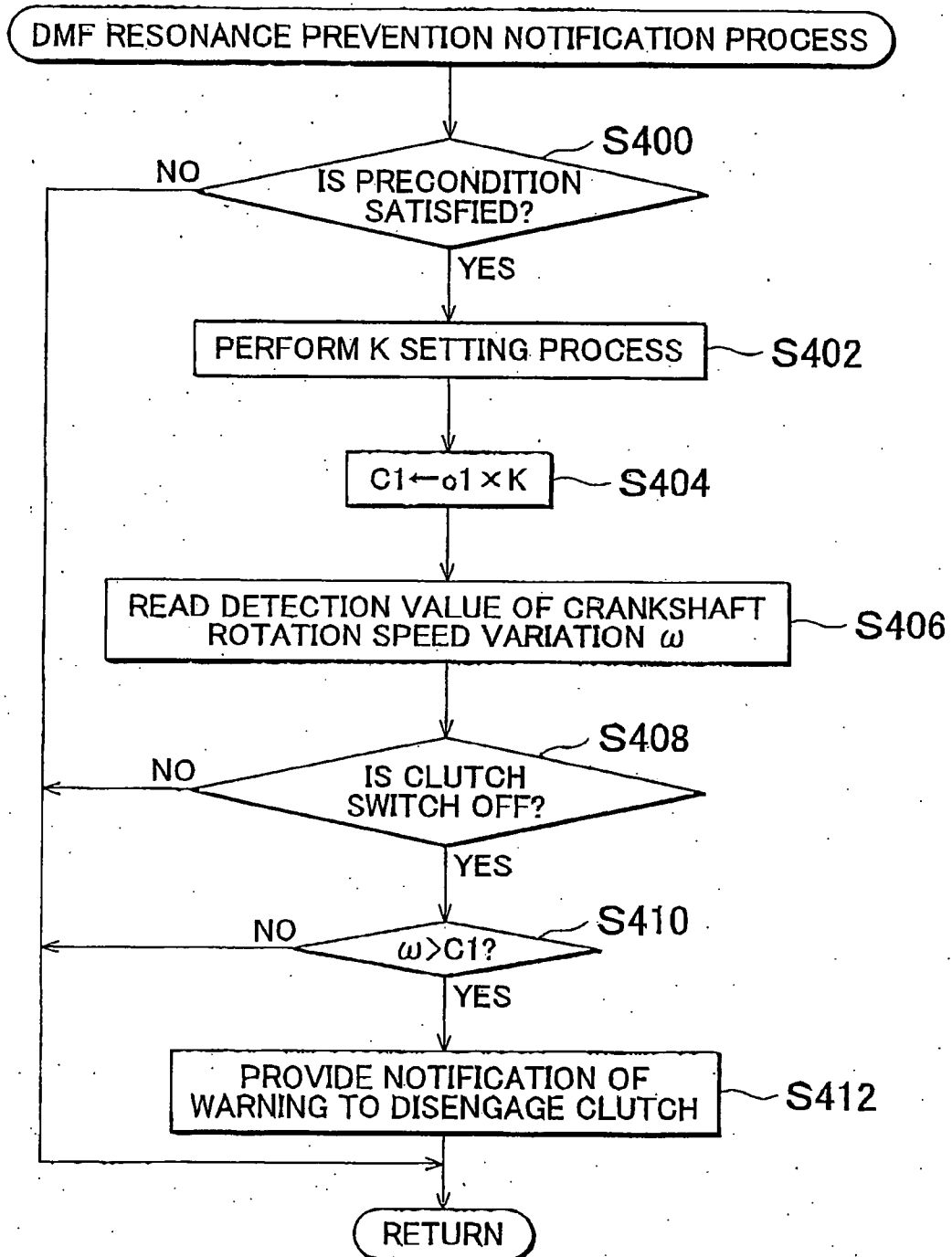


FIG. 15

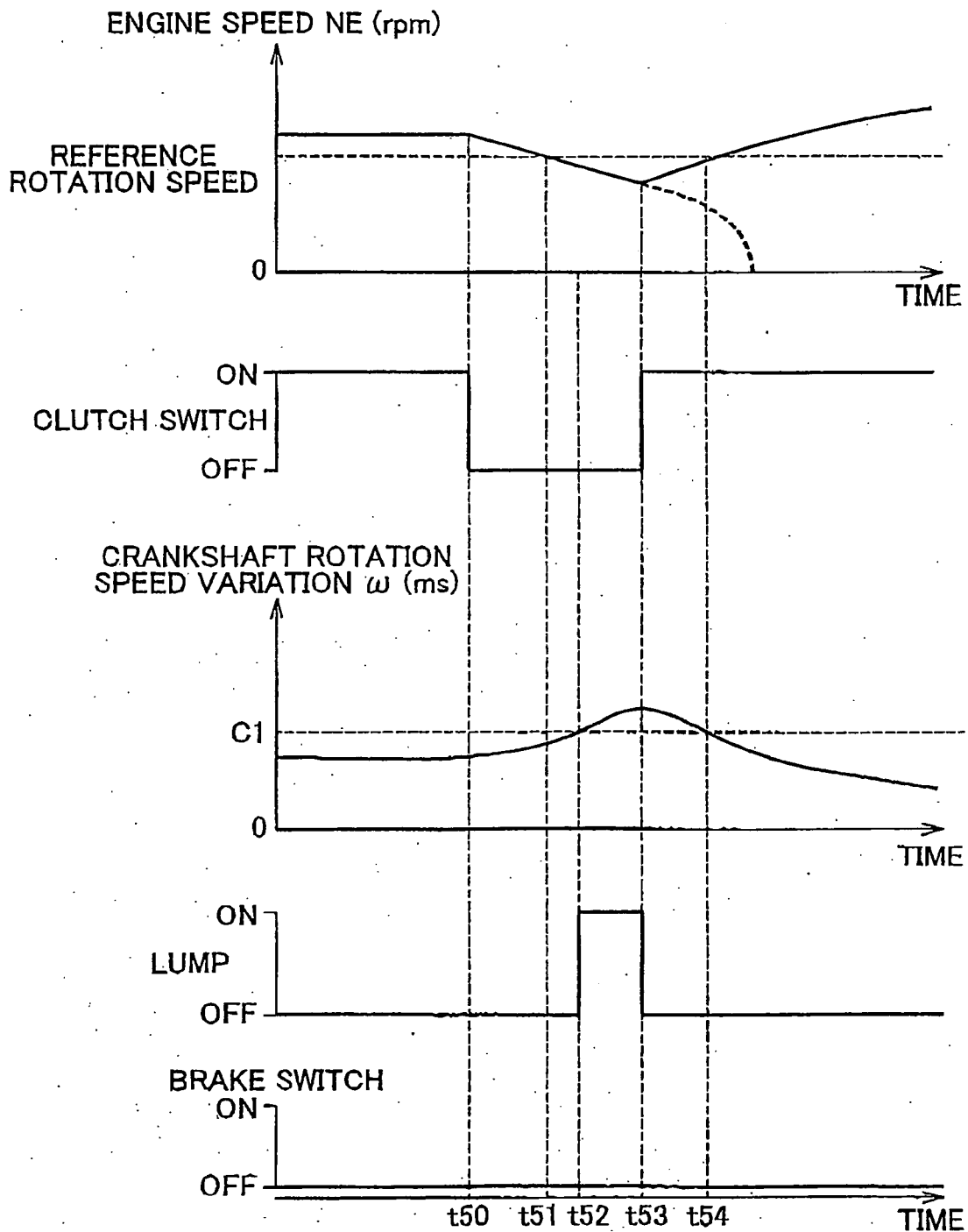


FIG. 16

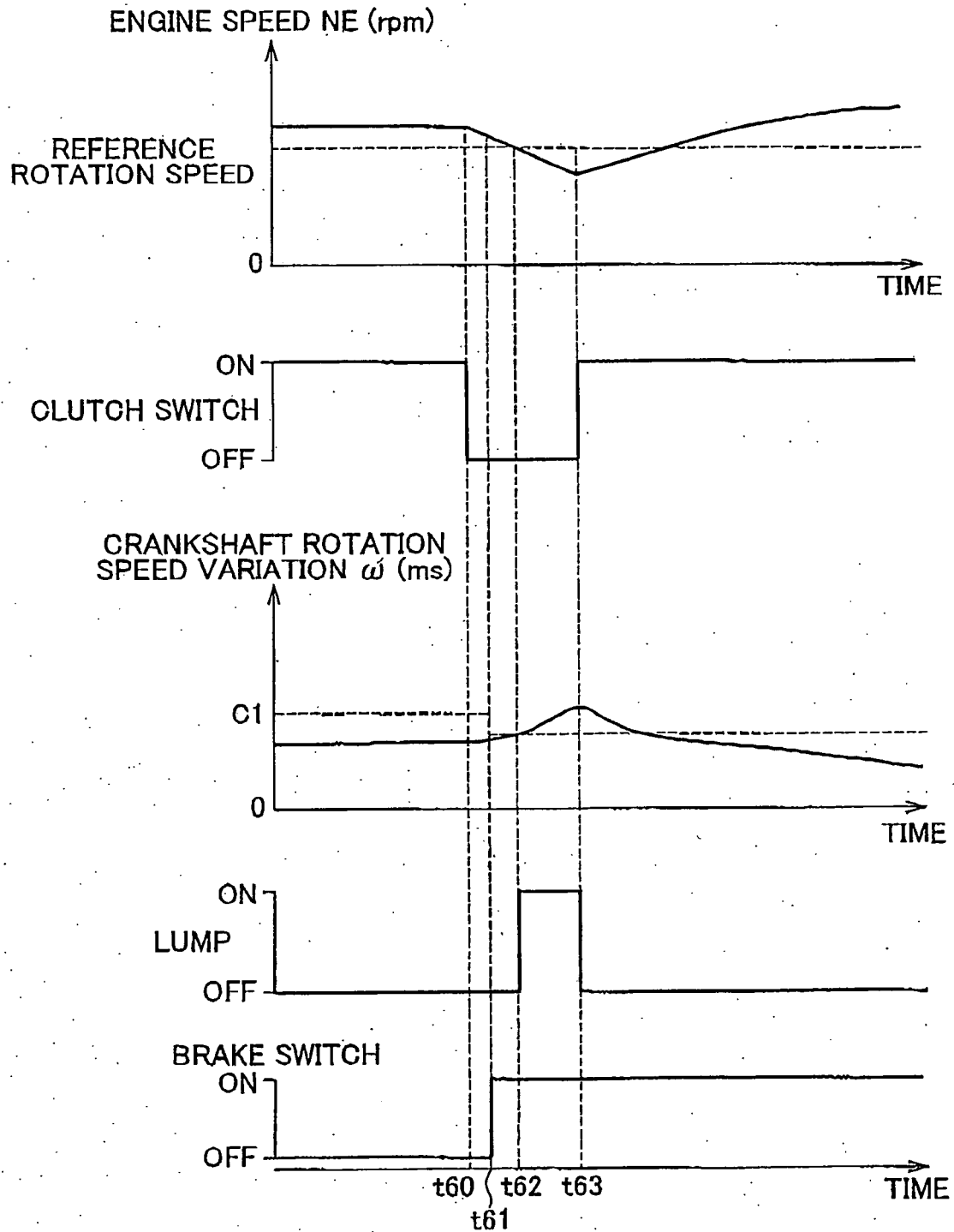
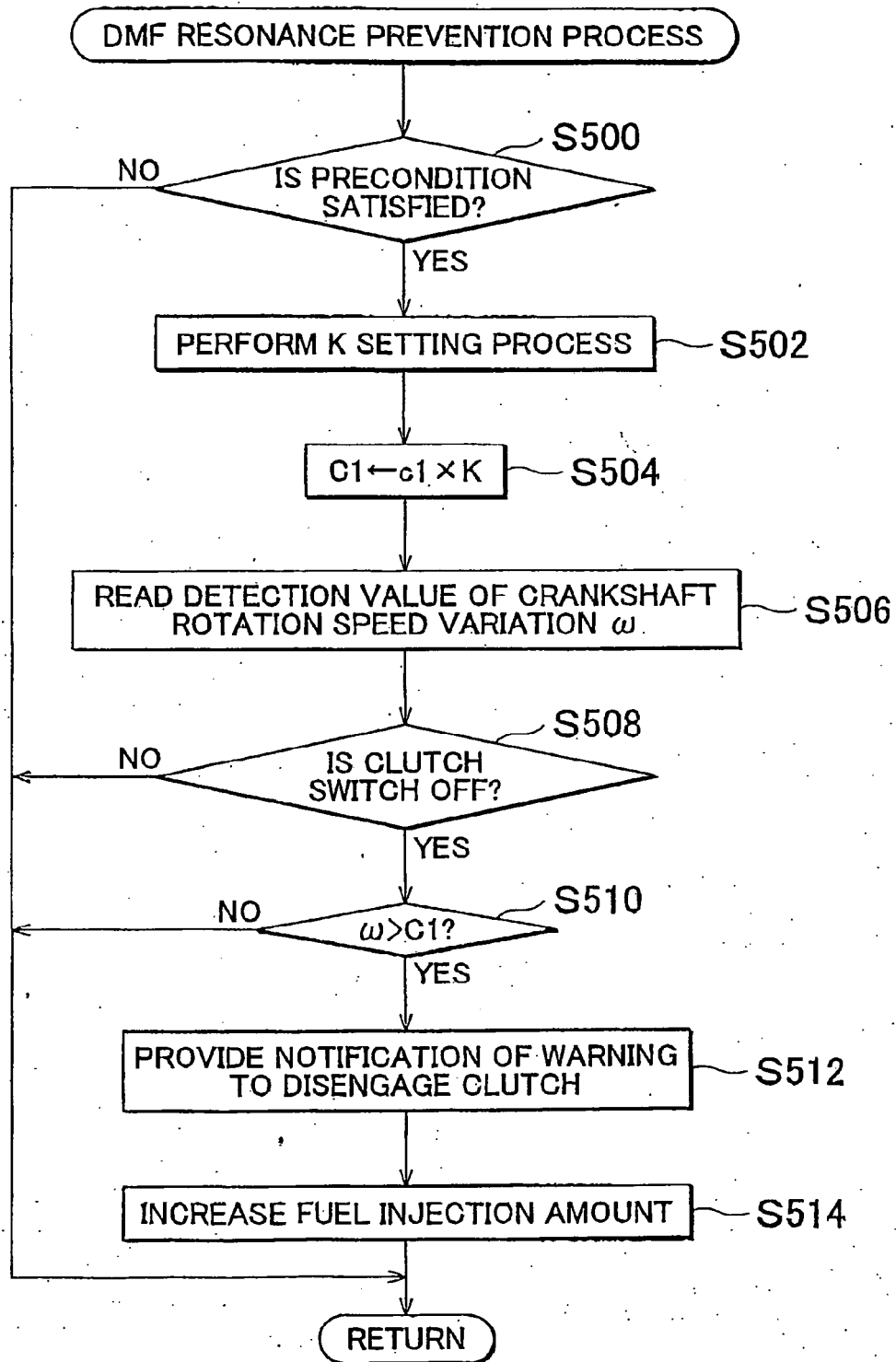


FIG. 17



REFERENCES CITED IN THE DESCRIPTION

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- JP 2002221059 A [0005] [0006] [0008]