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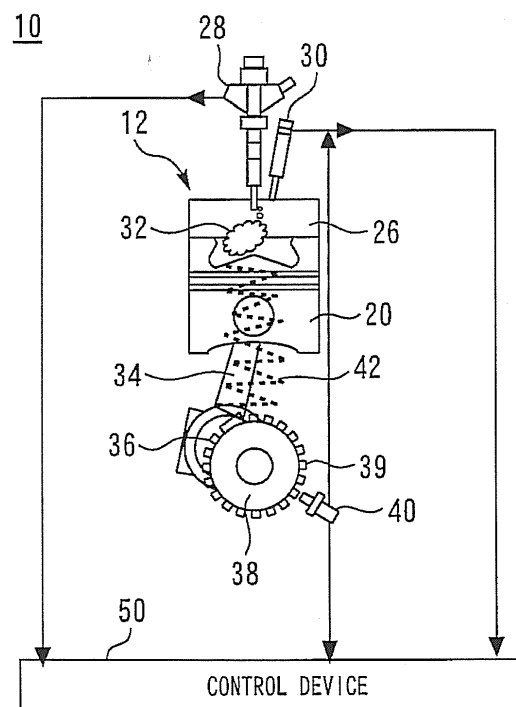
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(54) **INTERNAL COMBUSTION ENGINE WITH CRANK ANGLE SIGNAL BASED COMBUSTION NOISE CONTROL**

(57) An internal combustion engine (10) includes a crank angle sensor (40) and a control device (50). The control device (50) includes a function which defines a first relation between an input and a control amount of the internal combustion engine and a second relation between an input and a diagnosis result of the internal combustion engine. The control device (50) performs frequency analysis of a part of an output signal from the crank angle sensor (40). The part corresponds to a combustion stroke. The control device (50) inputs a value of a size of a frequency component into the function. The frequency component increases as combustion noise increases. The control device (50) performs control or diagnosis of the internal combustion engine in accordance with the control amount or the diagnosis result output from the function.

Fig. 1



Description

Background of the invention

Field of the Invention

[0001] The present invention relates to an internal combustion engine.

Background Art

[0002] An internal combustion engine is that performs control that suppresses combustion noise using an in-cylinder pressure sensor is already known, as disclosed, for example, in Japanese Patent Laid-Open No. 2006-233839. A control device described in the aforementioned publication determines whether or not combustion noise has become excessive based on whether or not an in-cylinder pressure change rate (that is, dP/dt or $dP/d\theta$) has become greater than a predetermined change rate dP_{th} .

[0003] Other prior art includes Japanese Patent Laid-Open No. 2011-117420 and Japanese Patent Laid-Open No. 2006-183533.

[0004] An in-cylinder pressure sensor includes a sensor portion that is directly exposed inside a cylinder. If unburned components inside the cylinder accumulate on the sensor portion, the sensitivity of the in-cylinder pressure sensor will decrease. Further, depending on the specifications of the internal combustion engine, there are many internal combustion engines in which an in-cylinder pressure sensor is not mounted. Therefore, the present inventor conducted extensive studies taking these points into consideration, and focused on a physical phenomenon whereby the size of a specific frequency component included in a crank angle speed waveform correlates with the magnitude of combustion noise. Thus, the present inventor discovered a novel technology for performing control or diagnosis of an internal combustion engine that relates to combustion noise utilizing this physical phenomenon.

Summary of the Invention

[0005] The present invention has been conceived to solve the problems described above, and an object of the present invention is to provide an internal combustion engine that can perform control or diagnosis of the internal combustion engine that relates to combustion noise by utilizing a fact that combustion noise occurs during rotation of a crankshaft.

[0006] According to a first aspect of the present invention an internal combustion engine includes: a crank angle sensor and a control device. The crank angle sensor outputs an output signal that corresponds to rotation of a crankshaft, the crankshaft is connected to a piston, and the piston is provided in a cylinder of the internal combustion engine. The control device includes a function,

the function defines a first relation or a second relation, the first relation is a relation between an input and a control amount of the internal combustion engine, and the second relation is a relation between an input and an diagnosis result of the internal combustion engine. The control device performs frequency analysis of at least a first part of an output signal from the crank angle sensor, and the first part corresponds to a combustion stroke of the cylinder. The control device inputs a value of a size of a frequency component into the function, the frequency component is in plural frequency components included in the first part of the signal, and the frequency component increases as combustion noise increases. The control device performs control or diagnosis of an internal combustion engine in accordance with the control amount or the diagnosis result outputted from the function. The frequency component increasing as the combustion noise increases may be a predetermined frequency.

[0007] According to a second aspect of the present invention, in the internal combustion engine according to the first aspect, the function may outputs the control amount so as to suppress the combustion noise to a greater degree as the inputted value increases.

[0008] According to a third aspect of the present invention, in the internal combustion engine according to the first aspect or the second aspect, the function may output a start signal or a stop signal for a control to suppress the combustion noise in accordance with the amount of the inputted value.

[0009] According to a fourth aspect of the present invention, in the internal combustion engine according to any one of the first to third aspects, the function may output the diagnosis result, the diagnosis result may indicate whether or not a combustion noise is abnormal in accordance with the amount of the inputted value.

[0010] According to a fifth aspect of the present invention, the internal combustion engine according to any one of the first to fourth aspects may further include an in-cylinder pressure sensor provided with the cylinder. In the fifth aspect, the control device may calculate the value of the size of the combustion noise based on an output signal from the in-cylinder pressure sensor, the function may output the diagnosis result in accordance with an amount of a difference between a first input and a second input, the first input is the value of the size based on an output signal from the crank angle sensor, the second input is a value of a size of combustion noise acquired by the in-cylinder pressure sensor, and the diagnosis result indicates whether at least one of the crank angle sensor and the in-cylinder pressure sensor.

[0011] According to a sixth aspect of the present invention, the internal combustion engine according to any one of the first to fifth aspects may further include an in-cylinder pressure sensor provided with the cylinder and a notifying means for notifying abnormality of the internal combustion engine. In the sixth aspect, the control device may calculate the value of the size of the combustion noise based on an output signal from the in-cylinder pres-

sure sensor, the function may output different signals to the notifying means in accordance with an amount of a difference between a first input and a second input, the first input is the value of the size based on an output signal from the crank angle sensor, and the second input is a value of a size of combustion noise acquired by the in-cylinder pressure sensor.

[0012] According to a seventh aspect of the present invention, the internal combustion engine according to any one of the first to sixth aspects may further includes a plurality of the cylinders. Each piston in each of the cylinders are connected to the crankshaft. The control device may input a value of a size of a frequency component into the function. The frequency component is in plural frequency components in the first part of the signal. The frequency component corresponds to an order that is half of a number of the cylinders.

[0013] According to a eighth aspect of the present invention, in the internal combustion engine according to any one of the first to seventh aspects, the control device may perform periodic sampling of an output signal from the crank angle sensor, the sampling is performed to a second part of the output signal, the second part is apart from the crank angular speed peak position, and the control device may perform frequency analysis of the second part acquired by the sampling.

[0014] According to a ninth aspect of the present invention, in the internal combustion engine according to the eighth aspect, the control device may increase an amount of a distance between the second part and the crank angular speed peak position as a noise transmission time period increases, and the noise transmission time period is a time period from a time point when the combustion noise occurs in the cylinder to a time point when the crank angle sensor detects the combustion noise.

[0015] According to the first invention, the size of a frequency component that corresponds to combustion noise in a sensor output signal is determined, and the size of this frequency component is included as an input variable in a function in which combustion noise and a control amount or a diagnosis result of the internal combustion engine are associated. As a result, control or diagnosis relating to combustion noise can be performed utilizing a sensor that can detect rotation of a crankshaft.

[0016] According to the second invention, control that suppresses combustion noise can be performed, and the suppression amount can be adjusted based on an output signal of a crank angle sensor.

[0017] According to the third invention, control that suppresses combustion noise can be executed or stopped by using the size of a frequency component that corresponds to the combustion noise as an index.

[0018] According to the fourth invention, the magnitude of combustion noise can be determined by using the size of a frequency component that corresponds to the combustion noise that is included in an output signal of the crank angle sensor as an index.

[0019] According to the fifth invention, by checking a divergence between combustion noises that is determined based on an output signal from the crank angle sensor and combustion noise that is determined based on an output signal from the in-cylinder pressure sensor, it is possible to diagnose whether at least one of these sensors is exerting the original performance thereof.

[0020] According to the sixth invention, by checking a divergence between combustion noise that is determined based on an output signal from the crank angle sensor and combustion noise that is determined based on an output signal from the in-cylinder pressure sensor, it is possible to diagnose whether at least one of these sensors is exerting the original performance thereof, and also recognize the diagnosis result from outside of the control device.

[0021] According to the seventh invention, since a frequency component to be assessed is determined in accordance with a timing at which a combustion timing appears in an output signal of the crank angle sensor, the combustion noise can be accurately assessed.

[0022] According to the eighth invention, since a configuration is adopted so as to sample an output signal at a specific timing that is suitable for combustion noise assessment, a component that is attributable to combustion noise in an output signal can be accurately extracted.

[0023] According to the ninth invention, by progressively retarding the sampling timing as the length of a noise transmission time period that is a time period until combustion noise is transmitted to the crank angle sensor increases, a portion in which combustion noise appears in an output signal can be accurately sampled.

Brief Description of the Drawings

[0024]

Fig. 1 is a view that illustrate an internal combustion engine according to a first embodiment of the present invention;

Fig. 2 is a view that illustrate an internal combustion engine according to a first embodiment of the present invention;

Fig. 3 is a view for describing contents of control of the internal combustion engine according to the first embodiment of the present invention;

Fig. 4 is a view for describing contents of control of the internal combustion engine according to the first embodiment of the present invention;

Fig. 5 is a view for describing contents of control of the internal combustion engine according to the first embodiment of the present invention;

Fig. 6 is a flowchart of a routine that the internal combustion engine according to the first embodiment of the present invention executes;

Fig. 7 is a flowchart of a routine executed by a control device for an internal combustion engine according to a modification of the first embodiment of the

present invention;

Fig. 8 is a flowchart of a routine that the control device for an internal combustion engine according to the second embodiment of the present invention executes; and

Fig. 9 is a flowchart of a routine that a control device for an internal combustion engine executes according to a modification of the second embodiment of the present invention.

Detailed Description of the Preferred embodiments

First Embodiment

[Configuration of Apparatus of First Embodiment]

[0025] Fig. 1 and Fig. 2 are views that illustrate an internal combustion engine according to a first embodiment of the present invention. Fig. 1 illustrates a side view as seen from an axial direction of a crankshaft of one cylinder in an internal combustion engine 10 (hereunder, referred to simply as "engine 10") according to the first embodiment, as well as a block diagram of a control device 50. Fig. 2 is a perspective view illustrating four cylinders (namely, cylinders #1 to #4) of the in-line four-cylinder engine 10. The engine 10 according to the present embodiment is a diesel engine.

[0026] As shown in Fig. 1, the engine 10 includes a cylinder 12. The cylinder 12 is formed in a cylinder block that is not illustrated in the drawing, and a piston 20 is provided inside the cylinder 12. The upper part of the cylinder 12 is covered with a cylinder head (not shown in the drawing), and a combustion chamber 26 is formed by the top face of the piston and the inner face of the cylinder head. The piston 20 is connected to a crankshaft 36 by a connecting rod 34.

[0027] An in-cylinder fuel injection valve 28 and an in-cylinder pressure sensor 30 are provided at the upper part of the cylinder 12. The cylinder 12 enters a combustion stroke when the in-cylinder fuel injection valve 28 injects a spray 32 composed of fuel into the combustion chamber 26. Combustion noise that occurs during the combustion stroke passes through the inside of the piston 20 from the top face of the piston 20 as indicated by vibrations 42 that are represented by a dashed line, and reaches the crankshaft 36 via the connecting rod 34. As shown in Fig. 2, the vibrations 42 from the respective pistons 20 of the cylinders #1 to #4 reach the crankshaft 36.

[0028] Note that, although in the present embodiment the engine 10 is assumed to be a diesel engine, the present invention is not limited thereto, and the engine 10 may also be a gasoline engine. In that case, a spark plug and either one of or both of a port injection valve and an in-cylinder injection valve are provided in the cylinder head that is not shown in the drawings.

[0029] A crankshaft timing rotor 38 is attached to an end portion of the crankshaft 36. The engine 10 includes

a crank angle sensor 40. By detecting signal teeth 39 and toothless portions (not illustrated in the drawings) of the crankshaft timing rotor 38, the crank angle sensor 40 can output an output signal that indicates a crank angle and a top dead center position. Preferably, the resolution of the crank angle detection by the crank angle sensor 40 is a high resolution of, for example, about one degree.

[0030] The engine 10 includes the control device 50. The control device 50 is an ECU (electronic control unit) which includes a hardware configuration such as a CPU that performs calculation processing, a RAM, a ROM, an input/output interface and the like. The control device 50 is connected to the in-cylinder fuel injection valve 28, the in-cylinder pressure sensor 30, the crank angle sensor 40, an unshown air flow meter, and various sensors such as an air-fuel ratio sensor which are not shown in the drawings. The control device 50 stores a program that calculates a fuel injection amount and a fuel injection timing of the in-cylinder fuel injection valve 28 based on output signals of the aforementioned various sensors. The control device 50 detects a crank angle based on an output signal of the crank angle sensor 40.

[0031] Note that, in the first embodiment and in a second embodiment that is described later, the control device 50 stores a function that defines a "relation between an input and an engine control amount" or a "relation between an input and an engine diagnosis result" in the ROM that is included therein. The term "function" as used herein broadly means something in which a correspondence relation between an output value and an input value is previously defined. That is, the term "function" as used herein includes: a program that calculates a numerical value by a mathematical computation; electronic data, such as a map, in which a plurality of sets of an input value and an output value are stored; and a program that outputs a Boolean value or a logical value in accordance with a magnitude relationship between an input value and a predetermined comparison value or a magnitude relationship between a plurality of input values. Further, an input value is not limited to one value, and may be a plurality of values. A value that is determined by frequency analysis processing that is described later is input into the function, and control or diagnosis of the engine 10 is performed in accordance with an engine control amount or a diagnosis result that the function outputs.

[Contents of Control of Device of First Embodiment]

[0032] Figs. 3 to 5 are views for describing contents of control of the internal combustion engine according to the first embodiment of the present invention. Fig. 6 is a flowchart of a routine that the internal combustion engine according to the first embodiment of the present invention executes. Hereunder, the contents of control of the control device 50 are described using these figures.

[0033] A spray component that is diffused perpendicularly to the combustion chamber 26 in the spray 32 greatly contributes to combustion noise. Vibrations that

arise when the spray component that is diffused perpendicularly is combusted are transmitted through the piston 20, the connecting rod 34, and the crankshaft 36. The transmitted vibrations influence the size of a specific frequency component included in a crank angle speed that is detected by the crank angle sensor 40.

[0034] Therefore, in the present embodiment, first, a frequency spectrum is determined with respect to a portion that corresponds to a combustion stroke of the cylinder 12 in the output signal of the crank angle sensor 40. Thereafter, the larger a component of a predetermined frequency is in the frequency spectrum, the greater the combustion noise is determined to be. The predetermined frequency is previously determined at a stage of designing or testing the engine 10 or the like, and is stored in a memory of the control device 50.

[0035] For convenience, a frequency that is used in the combustion noise determination will be described as a "frequency fb". In the case of the engine 10, the frequency fb is a frequency corresponding to a secondary rotational order. Since the engine 10 according to the present embodiment is a four-stroke, four-cylinder engine and combustion noise occurs in the secondary rotational order, the magnitude of combustion noise can be assessed by assessing the size of a frequency component that corresponds to the secondary rotational order. For engines in which the number of cylinders is other than four, a frequency component that corresponds to the rotational order that is half of the number of cylinders can be taken as the frequency fb. For example, if the engine has five cylinders, the size of a frequency component that corresponds to a rotational order of two and one half can be assessed, and if the engine has six cylinders, the size of a frequency component that corresponds to a tertiary rotational order can be assessed.

[0036] Note that, since, in practice, retardation or advancing of the fuel injection timing is performed in some cases, it is preferable to take a frequency corresponding to the secondary rotational order as a center frequency and define a frequency band of a predetermined width having a spread in the vicinity of the center frequency, and use the size of a frequency component included in the frequency band of the predetermined width for determining the combustion noise. For example, the maximum value of frequency components included in the frequency band may be used for determining the combustion noise.

[0037] In the routine illustrated in Fig. 6, first, the control device 50 executes processing to acquire a fuel injection amount (step S100), processing to determine a spray shape (step S102), and processing to acquire a fuel injection timing (step S104). Control target values that are calculated by the control device 50 may be used for the fuel injection amount and fuel injection timing. The spray shape is determined based on mechanical factors such as the nozzle direction of the in-cylinder fuel injection valve 28 and the shape of the intake port. Hence, according to the first embodiment, it is assumed that information indicating the spray shape is previously stored inside the

control device 50.

[0038] Next, the control device 50 executes piston position detection processing (step S106). In this step, the position of the piston 20 when the in-cylinder fuel injection valve 28 injected fuel is calculated based on the crank angle.

[0039] Next, the control device 50 executes processing to estimate a distance within the combustion chamber (step S108). Here, the term "distance within the combustion chamber" refers to a distance between the tip portion of an injector of the in-cylinder fuel injection valve 28 and the top face of the piston 20 inside the cylinder 12. Since the position of the tip portion of the injector of the in-cylinder fuel injection valve 28 is decided when designing the engine 10, the distance within the combustion chamber can be calculated using the piston position when combustion is detected in step S106.

[0040] Next, the control device 50 executes processing to acquire combustion cylinder information (step S110). In this step, the timings at which combustion occurs in each of the cylinders #1 to #4 are associated with an output signal of the crank angle sensor 40. Since the combustion order of the engine 10 is decided, it is possible to identify which portion of an output signal of the crank angle sensor 40 corresponds to the vicinity of a combustion stroke for which cylinder. Note that, as shown in Fig. 2, the crankshaft 36 has a definite length. The distance between the respective cylinders #1 to #4 and the crankshaft timing rotor 38 differs for each cylinder number, with the cylinder #1 being nearest thereto and the cylinder #4 being farthest away. Consequently, when calculating a "noise transmission time period" that is described later, this information regarding cylinder numbers may also be included in the calculation.

[0041] Next, the control device 50 executes sampling processing and processing to acquire the crank angle speed (step S112). Fig. 3 is a view that schematically illustrates a crank angle speed waveform of the internal combustion engine according to the first embodiment of the present invention. In the crank angle speed waveform, the crank angle speed is calculated based on a value of the crank angle indicated by an output signal of the crank angle sensor 40. The crank angle speed with respect to which the abscissa axis is taken as the time axis forms a waveform that reaches a peak at a fixed cycle as shown in Fig. 3.

[0042] In the crank angle speed waveform shown in Fig. 3, portions exist at which a greater amount of vibrations that are caused by combustion in each of the respective cylinders of the engine 10 appear. These portions are denoted by reference character X in Fig. 3. In the present embodiment, sampling is performed with respect to the output signal of the crank angle sensor 40 so as to extract only such portions at which a greater amount of vibrations that are caused by combustion appear.

[0043] The control device 50 changes the contents of the sampling processing with respect to the crank angle

speed waveform that is determined based on the output signal of the crank angle sensor 40, in accordance with which of the cylinders #1 to #4 is the object for combustion noise detection. More specifically, the contents of the sampling processing include a sampling start timing d_s , a sampling period T_s , and a sampling interval W_s .

[0044] The sampling start timing d_s , the sampling period T_s , and the sampling interval W_s are illustrated in Fig. 3. The sampling interval W_s is the length from a starting point to an ending point of the sampling, that is, the sampling width. The sampling period T_s is the period in which sampling is performed. The sampling start timing d_s is an amount by which the starting position of the sampling interval W_s is retarded on the basis of an angular speed peak position in the crank angle speed waveform.

[0045] In the first embodiment, the sampling interval W_s is optimized using processing described hereunder. As will be understood from the hardware configuration illustrated in Fig. 1 and Fig. 2, the top face and the main body of the piston 20, the connecting rod 34, and the crankshaft 36 are present on the path from the spray 32 to the crank angle sensor 40. It takes time until the combustion noise of the respective cylinders #1 to #4 that passes along this path is detected by the crank angle sensor 40. The amount of time taken to detect the combustion noise is also referred to as a "noise transmission time period".

[0046] When the noise transmission time period is short, an angular speed peak position in the crank angle speed waveform and a portion at which a greater amount of vibrations that are caused by combustion appear that are shown in Fig. 3 are close to each other. In contrast, when the noise transmission time period is long, the angular speed peak position in the crank angle speed waveform and a portion at which a greater amount of vibrations that are caused by combustion appear that are shown in Fig. 3 are far from each other. It is preferable to adopt a configuration such that, the longer the noise transmission time period is, the greater the extent to which the starting position of the sampling interval W_s that is based on the angular speed peak position is retarded. Therefore, the control device 50 is configured to increase or decrease the sampling start timing d_s in accordance with the length of the noise transmission time period.

[0047] Fig. 4 illustrates a map for calculating a noise transmission time period of the internal combustion engine according to the first embodiment of the present invention. In the first embodiment, the noise transmission time period is determined by conversion based on the diffusion speed of the spray 32 and the time taken for noise to be transmitted through the piston 20 and connecting rod 34 and the like after combustion. More specifically, a map is created in which a function that takes the spray shape, the fuel injection amount, the fuel injection timing and the above described distance within the combustion chamber as parameters is assigned to the abscissa axis, and the noise transmission time period is assigned to the ordinate axis, and the map is stored in

the memory of the control device 50. The fuel injection amount and the spray shape are used for determining the diffusion speed of the spray 32. The slower that the diffusion speed of the spray is and the greater that the above described distance within the combustion chamber is, the longer the distance over which the combustion noise is transmitted becomes and the longer the noise transmission time period becomes.

[0048] The control device 50 increases or decreases the sampling start timing d_s in accordance with the noise transmission time period acquired from the map shown in Fig. 4. As described above, according to the first embodiment, based on a fuel injection amount injected to the relevant cylinder 12, the timing of fuel injection to the cylinder 12, and the position of the piston 20 inside the cylinder 12, the starting point of the sampling interval can be optimized in accordance with the noise transmission time period that is the time taken for combustion noise inside the cylinder 12 to be transmitted to the crank angle sensor 40. Consequently, a portion at which the combustion noise appears in an output signal can be accurately sampled.

[0049] Next, the control device 50 executes frequency analysis processing with respect to a signal acquired by the sampling processing in step S112 (step S114). In this step, frequency analysis processing for analyzing a frequency component included in the signal acquired by the sampling processing is performed. Since various kinds of techniques, such as fast Fourier transformation, are already known as specific techniques for performing frequency analysis, and such a technique is not novel, a description thereof is omitted herein.

[0050] Fig. 5 illustrates a frequency spectrum obtained by frequency analysis with respect to the internal combustion engine according to the first embodiment of the present invention. Fig. 5 is a power spectrum in which the abscissa axis represents the rotational order and the ordinate axis represents the power of a signal.

[0051] As described above, the engine 10 is a four-stroke, four-cylinder engine, and hence combustion noise occurs in the secondary rotational order. Hence, the size of a frequency component corresponding to the secondary rotational order has a correlation with the size of the combustion noise. A frequency f_b illustrated in Fig. 5 is a frequency corresponding to the secondary rotational order. A value P_{fb} in Fig. 5 is a component at the frequency f_b in the frequency spectrum, and the value P_{fb} increases as the combustion noise increases. A component surrounded by a solid line in Fig. 5 is a component of the frequency corresponding to the secondary rotational order in the frequency spectrum. On the other hand, a component surrounded by a dashed line in Fig. 5 is a component of a frequency corresponding to a rotational order that is less than the secondary rotational order (that is, a primary rotational order or a rotational order of one and one half) in the frequency spectrum.

[0052] Next, the control device 50 performs filter processing that filters frequency components that are un-

related to combustion noise and selectively extracts the value P_{fb} (step S116). A frequency component that is not related to combustion is not added to a frequency component corresponding to the secondary rotational order. For example, it is known that misfires appears in a frequency component corresponding to a rotational order of one half, and that an engine friction or noise component appears in a frequency component corresponding to the tertiary rotational order or higher. Therefore, band elimination filter processing that does not pass a frequency component corresponding to the rotational order of one half or the tertiary rotational order or higher may be executed on the frequency analysis results. Further, a configuration may be adopted in which the resonance frequency of the engine 10 is previously checked, and a resonance frequency component is attenuated by filter processing.

[0053] Next, the control device 50 executes processing that calculates a combustion noise index value (step S118). The combustion noise index value is an index value that is calculated to a progressively larger value as the combustion noise increases. The larger that the value P_{fb} is, the larger the value the control device 50 calculates as the index value that represents the size of the combustion noise. By adopting this configuration, an index value that quantitatively represents the magnitude of the combustion noise can be calculated based on the output signal of the crank angle sensor 40.

[0054] Thereafter, the current routine ends. According to the routine illustrated in Fig. 6 described above, an index value that quantitatively represents the magnitude of the combustion noise can be calculated by taking the size of the value P_{fb} that is a frequency component corresponding to combustion noise included in the output signal of the crank angle sensor 40 as an index.

[0055] Note that, a configuration may also be adopted in which a combustion noise index value is not calculated, and which determines whether or not the combustion noise is abnormal in accordance with whether or not the value P_{fb} exceeds a threshold value P_{th} . Note that, in the routine illustrated in Fig. 6, combustion noise can be detected using the output signal of the crank angle sensor 40, and the output of the in-cylinder pressure sensor 30 is not used.

[Modification of First Embodiment]

[0056] Fig. 7 is a flowchart of a routine executed by a control device for an internal combustion engine according to a modification of the first embodiment of the present invention. The routine shown in Fig. 7 differs from the routine shown in Fig. 6 in the respect that the processing in steps S130 and S132 is provided instead of the processing in step S118.

[0057] In step S130, the control device 50 executes processing to determine whether or not the value P_{fb} is equal to or greater than the threshold value P_{th} . More specifically, if it is determined that the expression $P_{fb} \geq$

P_{th} is true, the processing advances to step S132, while if it is determined that the expression $P_{fb} \geq P_{th}$ is false, the current routine ends without a command to instruct the start of combustion noise suppression control being issued in step S132.

[0058] In step S132 a command that instructs the start of combustion noise suppression control is issued, and the control device 50 executes combustion noise suppression control. The combustion noise suppression control is control that adjusts various engine control amounts such as the fuel injection timing so as to suppress the combustion noise. Various techniques for performing combustion noise suppression control are known and, as described in the following, there are also various engine control amounts that are adjusted so as to suppress the combustion noise. For example, a technique disclosed in Japanese Patent Laid-Open No. 2005-315077 or Japanese Patent Laid-Open No. 2007-278175 may be used. For example, the combustion noise suppression control may be control that retards the fuel injection timing as described in Japanese Patent Laid-Open No. 2007-278175. Further, for example, Japanese Patent Laid-Open No. 2005-315077 discloses a technique that utilizes a pilot injection as combustion noise suppression means for suppressing the combustion noise of a combustion chamber, and controls the combustion noise at an arbitrary timing and to an arbitrary amount by controlling the existence/non-existence of a pilot injection as well as the amount and frequency thereof. In addition, Japanese Patent Laid-Open No. 2005-315077 includes a description to the effect that, as other combustion noise suppression means, for example, other means with which combustion conditions can be controlled can be utilized such as selectively decreasing the internal pressure of a delivery pipe by control of a high pressure pump, selectively decreasing a supercharging pressure in a vehicle in which a variable nozzle-type turbocharger (supercharger in which a movable nozzle vane is provided around a rotor blade of an exhaust-side turbine and in which the supercharging pressure is variable) is mounted, changing a valve timing or a valve lift amount by control of a VVT, or changing the ignition timing in the case of an engine, such as a gasoline engine, that uses a spark plug for ignition, and that an arbitrary combination of the foregoing means can also be utilized.

[0059] Thereafter, the current routine ends. According to the routine illustrated in Fig. 7 that is described above, attention is focused on the fact that a combustion noise component is added to an output signal of the crank angle sensor 40, and control that suppresses combustion noise can be executed by taking the size of a frequency component corresponding to the combustion noise that is included in the output signal of the crank angle sensor 40 as an index.

[0060] Note that, as a modification of the routine illustrated in Fig. 7, in the combustion noise suppression control in step S132, the control device 50 may adjust an engine control amount so as to suppress the combustion

noise to a progressively greater degree as the value Pfb increases. It is thereby possible to adjust an engine control amount so as to decrease the combustion noise based on an output signal of the crank angle sensor 40. More specifically, for example, similarly to the technology discussed in Japanese Patent Laid-Open No. 2007-278175, a configuration may be adopted that retards the fuel injection timing so as to decrease the combustion noise. Further, various engine control amounts with respect to the various combustion noise suppression means discussed in Japanese Patent Laid-Open No. 2005-315077 described above may also be adjusted. A configuration may also be adopted in which a function that previously defines the relation between the magnitude of combustion noise and various engine control amounts as disclosed in the foregoing known technology is stored in the memory of the control device 50 in the form of a mathematical computation program or a map. Note that, a configuration may also be adopted in which, by deleting step S130 from the routine in Fig. 7, the combustion noise suppression control in step S132 according to this modification is always performed.

[0061] Note that, in the first embodiment, the program in step S 118 in the flowchart in Fig. 6 corresponds to a "function that defines a relation between an input and an engine diagnosis result". Further, in the first embodiment, the processing in step S130 and the program in step S132 in the flowchart in Fig. 7 correspond to a "function that defines a relation between an input and an engine control amount".

Second Embodiment

[0062] A control device for an internal combustion engine according to the second embodiment includes the same hardware configuration as in the first embodiment, and the software processing that the control device executes is also common with the first embodiment. Accordingly, the following description centers on differences between the second embodiment and the first embodiment, and the same reference numerals are assigned to common components, and a description of contents that are common to the first embodiment is omitted or simplified hereunder.

[0063] The main difference between the first embodiment and the second embodiment is that, in the second embodiment, a value of combustion noise that is detected on the basis of an output signal from the in-cylinder pressure sensor 30 is used together with a value of combustion noise detected based on an output signal of the crank angle sensor 40. Further, in the second embodiment, the control device 50 executes the combustion noise control described in step S132 in Fig. 7 using a combustion noise index value determined based on an output signal of the in-cylinder pressure sensor 30.

[0064] Fig. 8 is a flowchart of a routine that the control device for an internal combustion engine according to the second embodiment of the present invention exe-

cutes. In the second embodiment, the control device 50 executes the routine shown in Fig. 8.

[0065] In the routine shown in Fig. 8, first, the control device 50 calculates a combustion noise index value CNcps that is calculated based on an output signal of the in-cylinder pressure sensor 30 (step S200). The combustion noise index value CNcps is a parameter value having a correlation with the magnitude of combustion noise. The combustion noise index value CNcps may be calculated, for example, based on dP/dt or $dP/d\theta$. Since various techniques are already known as techniques for detecting combustion noise based on the output signal of the in-cylinder pressure sensor 30, and such a technique is not novel, a description thereof is omitted herein.

[0066] Note that, it is supposed that a "parameter value having a correlation with the magnitude of combustion noise" that is calculated using those various known techniques may be expressed using various units depending on the case, and it is also supposed that a combustion noise index value CNcr described below may not necessarily be the same unit. In such a case, it is sufficient to match the units by converting the units to a common unit (for example, decibels dB).

[0067] Next, the control device 50 calculates a combustion noise index value CNcr that is calculated based on the output signal of the crank angle sensor 40 (step S202). The combustion noise index value CNcr to be calculated in this step can be calculated by executing the routine illustrated in Fig. 6 in the above described first embodiment.

[0068] Next, the control device 50 executes processing to determine whether or not the condition shown in the following Expression (1) holds (step S204).

$$|CNcps - CNcr| < CNth1 \quad \dots (1)$$

[0069] CNth1 in Expression (1) is a correction threshold value for determining a decrease in the output of the in-cylinder pressure sensor 30. The correction threshold value is a threshold value for determining whether or not there is a tendency for the sensitivity of the in-cylinder pressure sensor 30 to decrease. A problem can arise whereby the sensitivity of the in-cylinder pressure sensor 30 decreases and the reliability declines due to unburned components, soot or HC accumulating at a sensor portion of in-cylinder pressure sensor 30. Therefore, in the second embodiment a decrease in the sensitivity of the in-cylinder pressure sensor 30 is detected using the correction threshold value.

[0070] If the condition in Expression (1) does not hold, it means that an absolute value of a difference between CNcps and CNcr is less than the correction threshold value CNth1. In that case, the processing returns to step S200.

[0071] If the condition in Expression (1) holds, it means that the absolute value of the difference between CNcps

and CNcr is equal to or greater than the correction threshold value CNth1. In this case, a divergence between CNcps and CNcr increases in accordance with the degree to which a decline in the sensitivity of the in-cylinder pressure sensor 30 is recognized. Therefore, in the second embodiment, next, processing is executed that determines whether or not the condition shown in the following Expression (2) holds (step S206).

$$|CNcps - CNcr| < CNth2 \quad \dots (2)$$

Provided, CNth1 < CNth2.

[0072] CNth2 in Expression (2) is a failure threshold value for detecting a failure of the in-cylinder pressure sensor 30, and is set to a larger value than the aforementioned correction threshold value.

[0073] If the condition in Expression (2) holds, it means that the absolute value of a difference between CNcps and CNcr is less than the threshold value CNth2. In this case, it can be determined that although there is a decrease in the sensitivity of the in-cylinder pressure sensor 30, the decrease in sensitivity is not large enough to constitute a failure. Therefore, in the second embodiment the control device 50 executes processing to calculate a corrected index value CNcpssc in accordance with the following Expression (3) (step S208).

$$CNcps + CNcor = CNcpssc \quad \dots (3)$$

[0074] The correction value CNcor may be set in advance or may be a fixed value, and may be made variable so that, the greater that a difference between the CNcps and the CNcr is, the larger the value the correction value CNcor becomes in proportion thereto.

[0075] Thereafter, the routine returns to step S202, and the control device 50 then executes steps S204 and S206 again in sequence. Further, the control device 50 performs control of the engine 10 using the corrected index value CNcpssc that was calculated in step S208.

[0076] In contrast, in a case where the condition in Expression (2) holds, it means that the absolute value of the difference between CNcps and CNcr is equal to or greater than the threshold value CNth2. In this case, it can be determined that a decrease in the sensitivity of the in-cylinder pressure sensor 30 is too large. Therefore, in this case, the control device 50 stops the combustion noise control that was being performed using the combustion noise index value CNcps (step S210), and ends the current routine. Note that, it is sufficient to use the various known techniques described in the first embodiment for the combustion noise control.

[0077] According to the specific control of the second embodiment that is described above, it is possible to determine whether or not there is any kind of abnormality such as a decrease in sensitivity or a failure of the in-

cylinder pressure sensor 30. Further, a change in the sensitivity of the output of the in-cylinder pressure sensor 30 can be compensated for based on combustion noise that is determined based on an output signal of the crank angle sensor 40.

[0078] Note that, in the second embodiment, whether or not there is any kind of abnormality such as a decrease in sensitivity or a failure of the in-cylinder pressure sensor 30 is determined based on the premise that the output of the crank angle sensor 40 is correct. However, the present invention is not limited thereto. For example, a configuration may also be adopted in which, when it is determined in step S206 that the absolute value of a difference between CNcps and CNcr is equal to or greater than the threshold value CNth2, it is determined in step S210 that both of the crank angle sensor 40 and the in-cylinder pressure sensor 30 are abnormal. Alternatively, in contrast to the second embodiment, a configuration may be adopted in which, when the absolute value of the difference between CNcps and CNcr is equal to or greater than the threshold value CNth2, on the basis of the premise that the output of the in-cylinder pressure sensor 30 is correct, it is determined in step S210 that there is some kind of abnormality in the crank angle sensor 40. By checking the divergence between the combustion noises determined based on the output signal of the crank angle sensor 40 and the combustion noise determined based on the output signal of the in-cylinder pressure sensor 30, it is possible to diagnosis whether each of these sensors is exerting the original performance thereof.

[0079] Further, although in the second embodiment, in addition to the above described abnormality determination, the correction processing in step S208 is performed to compensate for a change in the sensitivity of the output of the in-cylinder pressure sensor 30 based on the combustion noise index value CNcr, the present invention is not limited thereto. A configuration may also be adopted so as to perform only the abnormality determination with respect to the in-cylinder pressure sensor 30 in the routine shown in Fig. 8, and not to perform the processing to calculate a combustion noise correction value. Conversely, a configuration may be adopted that performs only the correction processing in the routine shown in Fig. 8, and does not perform the processing to determine an abnormality of the in-cylinder pressure sensor 30.

[0080] Fig. 9 is a flowchart of a routine that a control device for an internal combustion engine executes according to a modification of the second embodiment of the present invention. The processing flows that are included in Fig. 8 and Fig. 9 are the same, except that the processing illustrated in Fig. 9 includes processing in step S220 instead of the processing in step S210 in Fig. 8. Further, according to this modification, the control device 50 is connected to an MIL (malfunction indicator light) for notify the occurrence of a malfunction.

[0081] In the routine shown in Fig. 9, in a case where the absolute value of a difference between CNcps and

CNcr in step S206 is equal to or greater than the threshold value CNth2, the control device 50 turns on the MIL (step S220). As a result, the result of the abnormality diagnosis can be recognized from outside the control device 50. Note that, instead of turning on the MIL, information may be communicated by another method that serves as a malfunction notification, such as an image or a sound.

[0082] Note that, in the second embodiment, the program in steps S206 and S210 in the flowchart in Fig. 8 corresponds to a "function that defines a relation between an input and an engine diagnosis result". Further, in the second embodiment, the program in steps S206 and S220 in the flowchart in Fig. 9 corresponds to a "function that defines a relation between an input and an engine diagnosis result".

Claims

1. An internal combustion engine comprising:

a crank angle sensor (40) outputting an output signal that corresponds to rotation of a crankshaft (36), the crankshaft (36) connected to a piston, the piston provided in a cylinder (12) of the internal combustion engine; and

a control device (50) including a function, the function defining a first relation or a second relation, the first relation being a relation between an input and an control amount of the internal combustion engine, the second relation being a relation between an input and an diagnosis result of the internal combustion engine, the control device (50) performing frequency analysis of at least a first part of an output signal from the crank angle sensor (40), the first part corresponding to a combustion stroke of the cylinder (12), the control device (50) inputting a value of a size of a frequency component into the function, the frequency component being in plural frequency components included in the first part of the signal, the frequency component increasing as combustion noise increases, the control device (50) performing control or diagnosis of an internal combustion engine in accordance with the control amount or the diagnosis result outputted from the function.

2. The internal combustion engine according to claim 1, wherein

the function outputs the control amount so as to suppress the combustion noise to a greater degree as the inputted value increases.

3. The internal combustion engine according to claim 1 or 2, wherein

the function outputs a start signal or a stop signal for a control to suppress the combustion noise in ac-

cordance with the amount of the inputted value.

4. The internal combustion engine according to any one of claims 1 to 3, wherein

the function outputs the diagnosis result, the diagnosis result indicates whether or not a combustion noise is abnormal in accordance with the amount of the inputted value.

5. The internal combustion engine according to any one of claims 1 to 4, further comprising an in-cylinder pressure sensor (30) provided with the cylinder (12), wherein

the control device (50) calculates the value of the size of the combustion noise based on an output signal from the in-cylinder pressure sensor (30), the function outputs the diagnosis result in accordance with an amount of a difference between a first input and a second input, the first input is the value of the size based on an output signal from the crank angle sensor (40), the second input is a value of a size of combustion noise acquired by the in-cylinder pressure sensor (30), the diagnosis result indicates whether at least one of the crank angle sensor (40) and the in-cylinder pressure sensor (30).

6. The internal combustion engine according to any one of claims 1 to 5, further comprising:

an in-cylinder pressure sensor (30) provided with the cylinder (12); and

a notifying means (S220) for notifying abnormality of the internal combustion engine; wherein the control device (50) calculates the value of the size of the combustion noise based on an output signal from the in-cylinder pressure sensor (30),

the function outputs different signals to the notifying means (S220) in accordance with an amount of a difference between a first input and a second input, the first input is the value of the size based on an output signal from the crank angle sensor (40), the second input is a value of a size of combustion noise acquired by the in-cylinder pressure sensor (30).

7. The internal combustion engine according to any one of claims 1 to 6, further comprising a plurality of the cylinders (12), each piston in each of the cylinders (12) connected to the crankshaft (36), wherein

the control device (50) inputs a value of a size of a frequency component into the function, the frequency component being in plural frequency components in the first part of the signal, the frequency component corresponds to an order that is half of a number of the cylinders (12).

8. The internal combustion engine according to any one

of claims 1 to 7, wherein

the control device (50) performs periodic sampling (S112) of an output signal from the crank angle sensor (40), the sampling is performed to a second part of the output signal, the second part is apart from the crank angular speed peak position, and the control device (50) performs frequency analysis of the second part acquired by the sampling (S112).

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9. The internal combustion engine according to claim 8, wherein

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the control device (50) increases an amount of a distance (ds) between the second part and the crank angular speed peak position as a noise transmission time period increases, the noise transmission time period is a time period from a time point when the combustion noise occurs in the cylinder (12) to a time point when the crank angle sensor (40) detects the combustion noise.

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Fig. 1

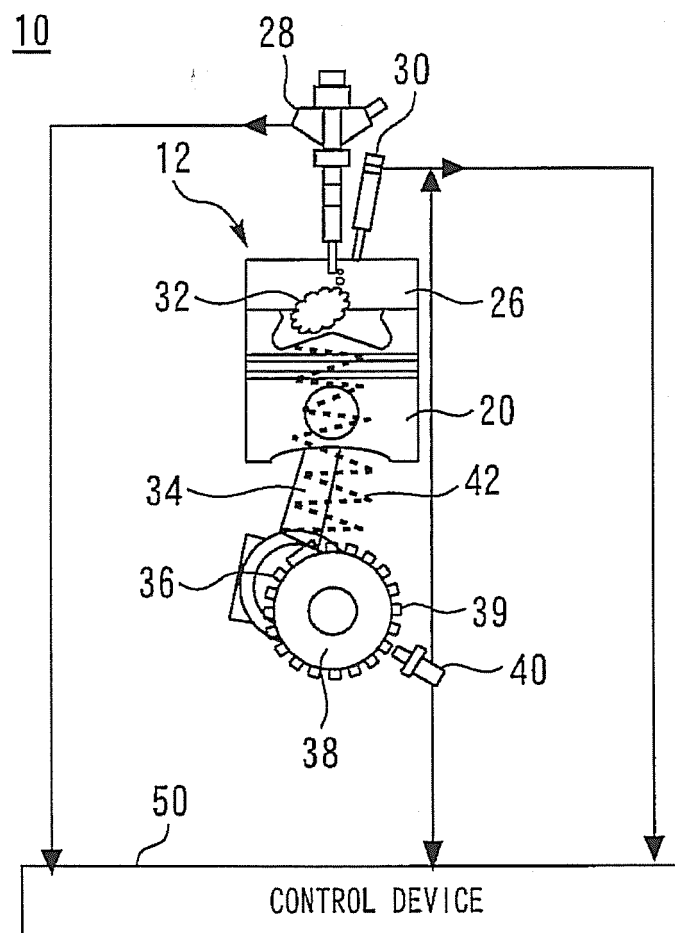


Fig. 2

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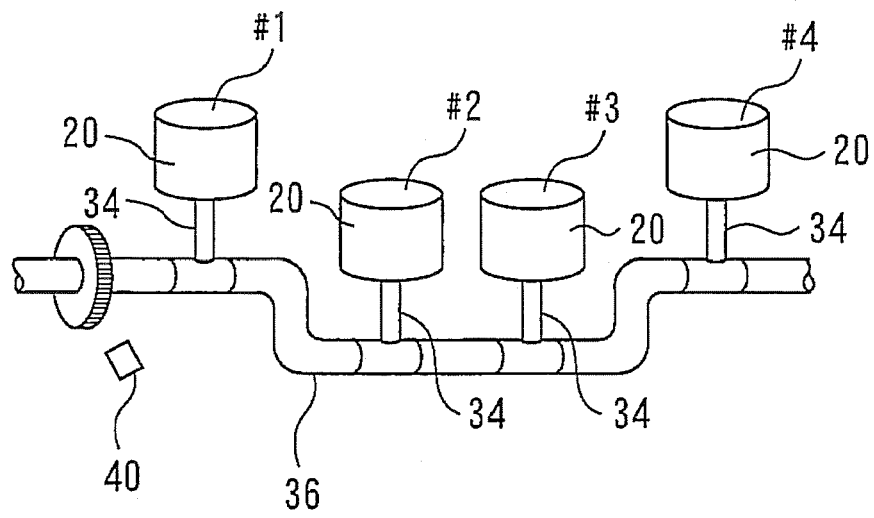


Fig. 3

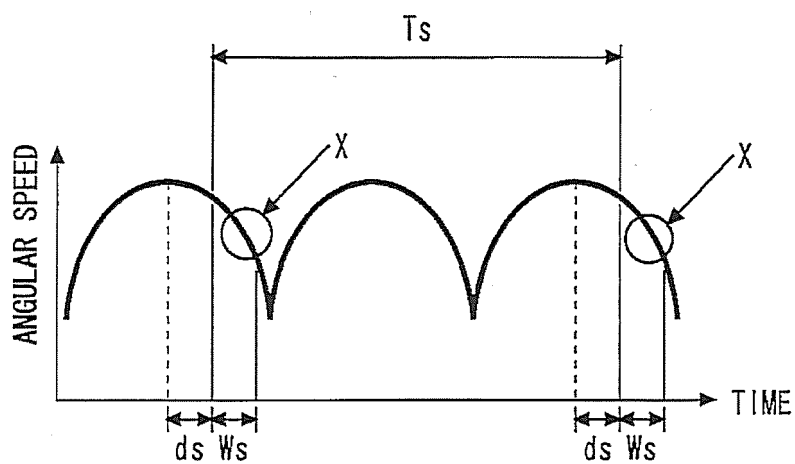


Fig. 4

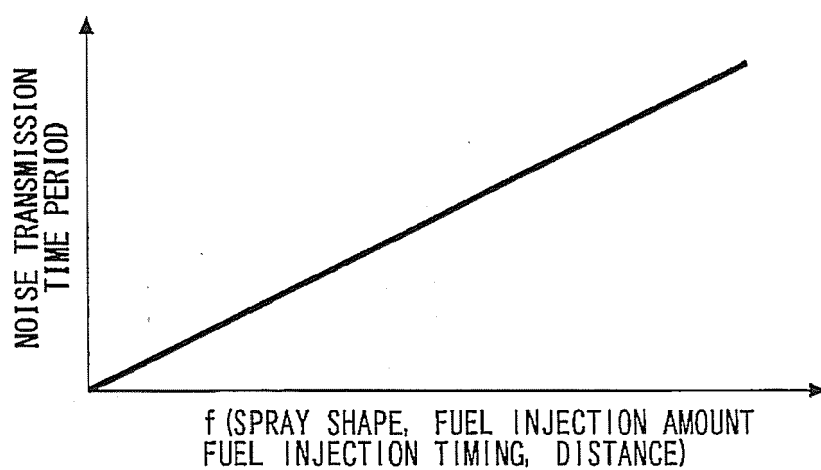


Fig. 5

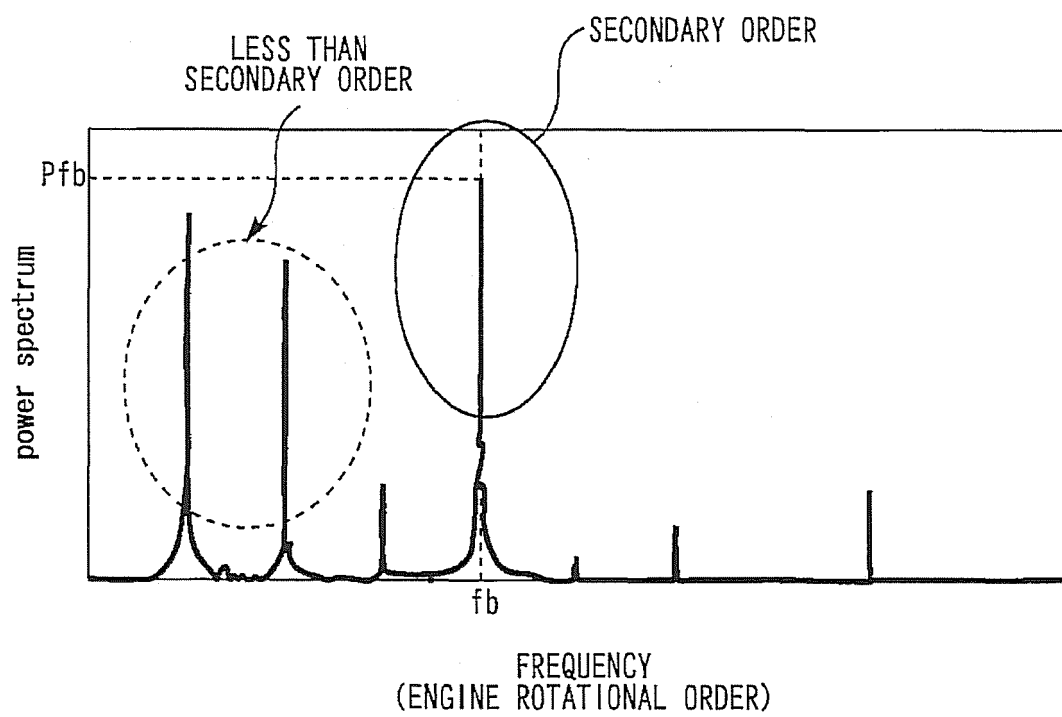


Fig. 6

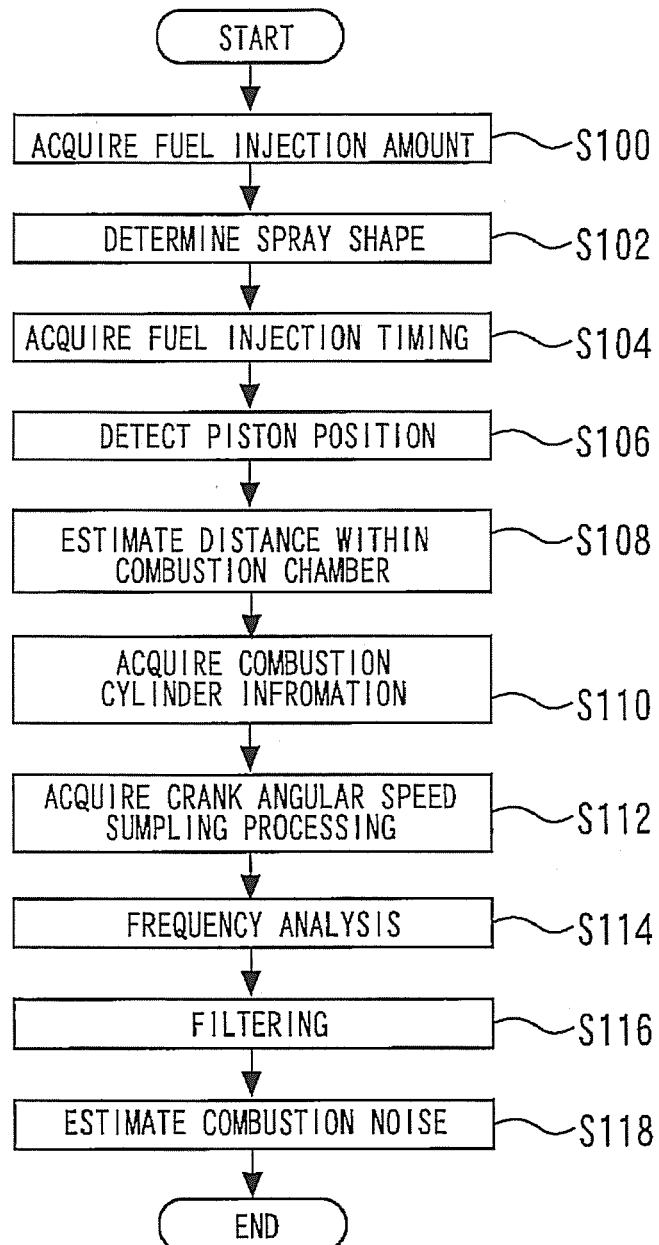


Fig. 7

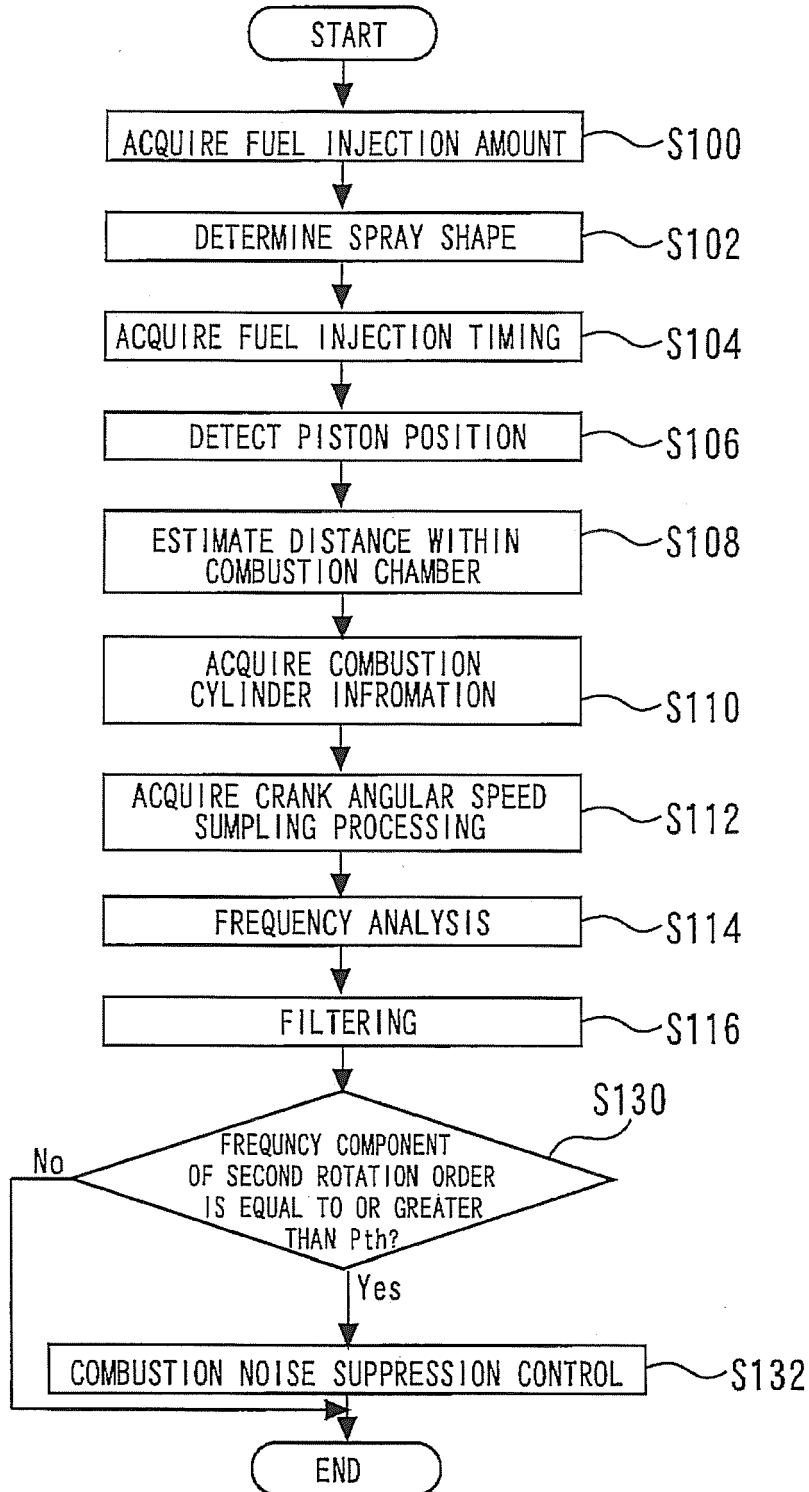


Fig. 8

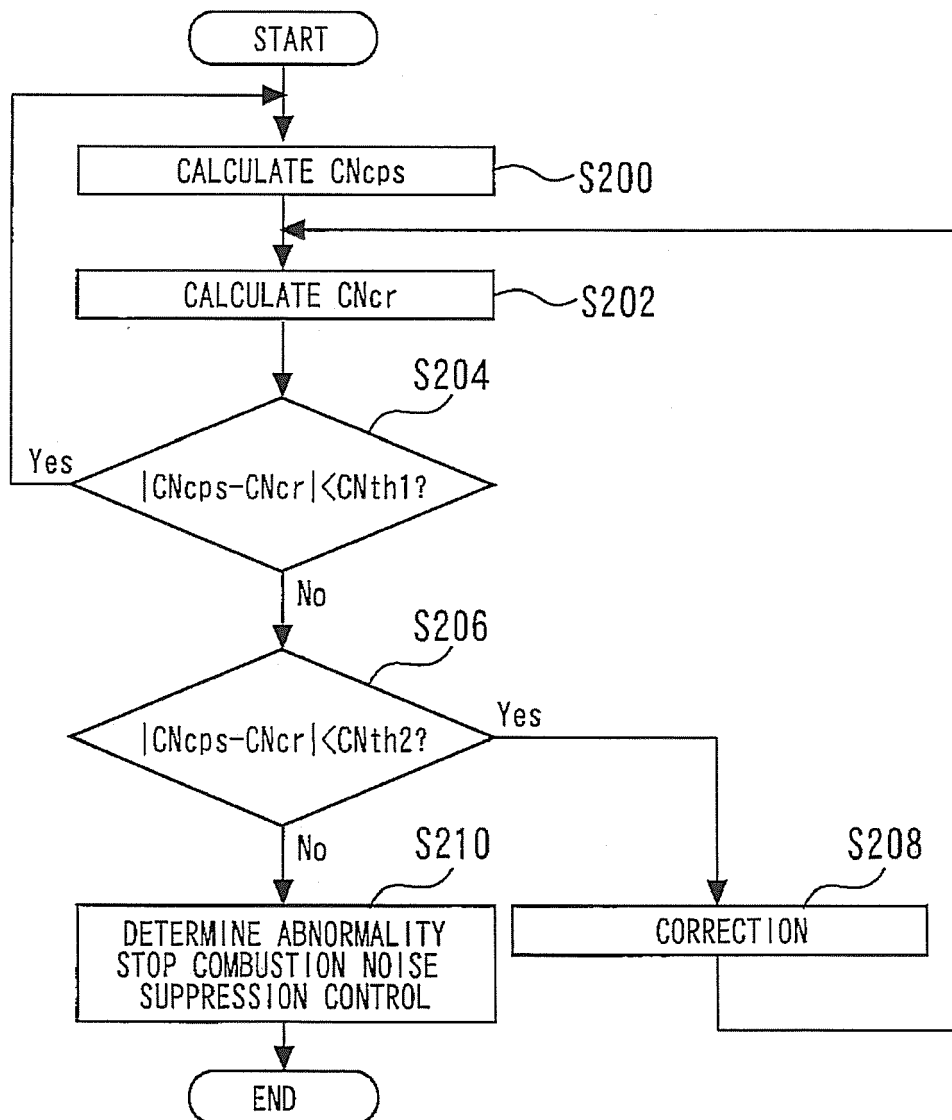
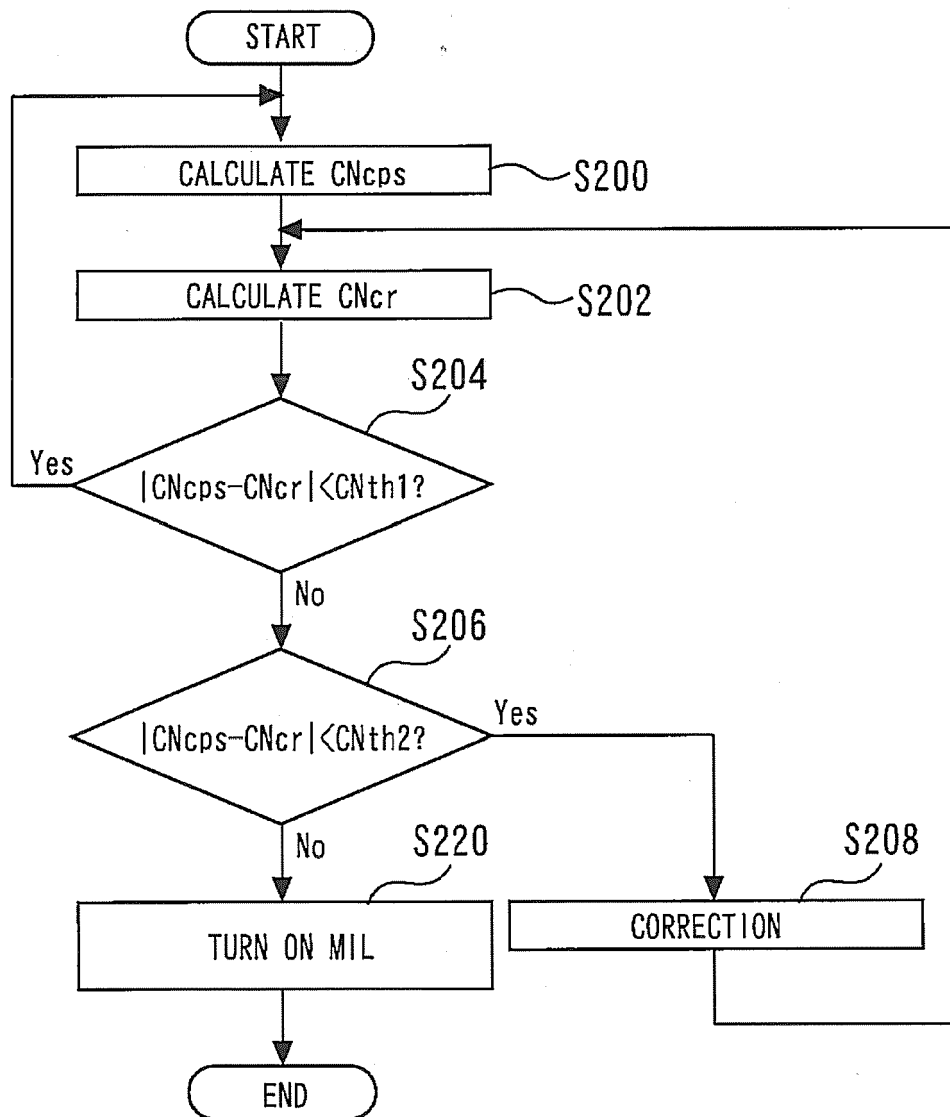


Fig. 9





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