

ACTIVE NOISE CONTROL SYSTEM WITH TUNING FUNCTION AND TUNING METHOD THEREOF

TECHNICAL FIELD

[0001] The present invention relates to an active noise control system with a tuning function which can easily perform a tuning operation, and a tuning method of the same.

BACKGROUND ART

[0002] A sound generated from a fan, a facility equipment such as an outdoor equipment and an excavator such as a backhoe among machines used in a factory and a construction site has a frequency characteristic that a sound pressure is particularly higher than the other frequencies in a low frequency domain (about 100 Hz or lower).

[0003] As a technique of lowering and controlling the sound having a specific frequency such as having a high sound pressure through the use of a sound interference phenomenon, an active noise control system has been provided. For example, Patent Literature 1 has been known for this system.

[0004] The active noise control system and the active noise control method described in Patent Literature 1 is provided with a measuring microphone which measures noise, a control controller which generates and outputs a control sound for reducing the noise, and a control speaker which emits the control sound, in which the control controller is constructed by including a bandpass filter which allows only a frequency component of a controlled object frequency band in the noise to pass through, an adaptive filter which estimates a controlled object dominant frequency from the frequency component passing through the bandpass filter, and a control signal operation unit which performs a phase correction according to a time control for a phase delay with respect to the control object dominant frequency on the basis of the phase delay for every previously measured frequency of the control controller and generates a control sound of an opposite phase thereto.

CITATION LIST

PATENT LITERATURE

[0005] Patent Literature 1: Japanese Unexamined Patent Publication No. 2015-225130

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] As described in Patent Literature 1, in the active noise control system (hereinafter, also refer to as system), a phase delay is generated in the control sound output from the control speaker rather than an actual sound measured by the measuring microphone and input into the system, on the basis of a characteristic of the system itself processing sound in addition to the control controller.

[0007] Accordingly, as described in Patent Literature 1, it is necessary to perform a phase correction, for example, on the basis of the previously measured phase delay of the control controller, that is, in prospect of the phase delay. Further, the correction is performed as occasion demands, for the gain of the control sound.

[0008] It is necessary to apply the tuning to the phase delay and the gain generated from the characteristic of the system itself before executing the active noise control in an actual place where a noise source such as a backhoe exists.

[0009] Without this procedure, the active noise control can not be appropriately executed actually in the actual place.

[0010] When getting the phase delay and the gain and appropriately performing the previous tuning, the following procedures are performed.

[0011] A system reference microphone (hereinafter, refer to as reference microphone) measuring sweep sound to the system is installed at a position of the noise source such as an engine of the backhoe corresponding to the noise source.

[0012] A tuning microphone measuring output sound (control sound) from the system is installed at a position of the control speaker.

[0013] Further, a sound source speaker emitting input sound is installed as a sound source for tuning at a position of the noise source.

[0014] Further, the system is operated, the input sound is measured by the reference microphone, and the output sound generated for the input sound and emitted is measured by the tuning microphone, so that the phase delay and the gain in the system are measured.

[0015] However, it is physically impossible to install the sound source speaker while overlapped at the position of the noise source, in the actual place.

[0016] In order to measure the phase delay and the gain generated in the system and tune the system, the measurement and the tuning could not be conventionally performed in the actual place where the noise source exists, but has been necessarily performed in the other facilities.

[0017] The tuning operation for the system in the other facilities has been performed, for examples, as follows.

[0018] Fig. 6 shows an example of an equipment configuration of the tuning operation in the other facilities, and Fig. 7 shows a tuning work flow.

[0019] A system a installed in an actual place having a noise source is constructed by a reference microphone b for measuring a sound of the noise source (input sound in tuning), a microphone amplifier c which amplifies the input sound (noise) from the reference microphone b, a control controller d which has a bandpass filter or an adaptive filter and an operation unit for processing the measured sound from the microphone amplifier c, a power amplifier e which amplifies the control sound from the control controller d (output sound in tuning), and a control speaker f which emits the output sound (control sound) from the power amplifier e.

[0020] Further, in the tuning operation of the system a, the system a is provided as additional equipment, with a sweep sound generator g which generates a sweep sound for the tuning operation, a power amplifier h which amplifies the sweep sound from the sweep sound generator g, a sound source speaker i which emits the sweep sound from the power amplifier h and

is an alternative to the noise source in the actual place, a tuning microphone j which measures the output sound of the sweep sound emitted from the sound source speaker i and emitted from the control speaker f through the system a, a microphone amplifier k which amplifies the measured sound from the tuning microphone j, a data recorder l which records the sound data of the measured sound input from the microphone amplifier k, and a personal computer m (hereinafter, refer to as PC in the drawing) which analyzes a phase delay and a gain generated in the system a from the sound data of the input sound and the output sound recorded by the data recorder l for performing the tuning operation setting the control controller d. A calibrator for adjusting the reference microphone b and the tuning microphone j is also provided.

[0021] Further, in the noise control by the system a, in order to adjust the amplitude of the sound generated from the noise source to the amplitude of the sound emitted from the control speaker f and accurately invert the phase, the respective positions of the reference microphone b and the tuning microphone j are severely set so as to have an equal distance from both the sound source speaker i and the control speaker f (shown by a distance x in Fig. 6).

[0022] In the tuning operation, first of all, the PC “generates a parameter data of a bandpass filter”, “generates a parameter data of an adaptive filter”, and “generates a gain of the system a and a correction data (which is not corrected yet in this stage) of a phase difference (phase delay)”.

[0023] Next, an anechoic chamber n is used as the other facilities, and the system a and an additional equipment are installed in this anechoic chamber n.

[0024] Further, it “outputs a sweep sound from the sound source speaker i in the anechoic chamber n, and confirms a gain of an input sound measured by the reference microphone b and input to the system a and a gain (sound pressure) of an output sound output from the control speaker f”.

[0025] It “records a calibration signal by the reference microphone b and the tuning microphone j through the use of a calibrator”, and stores in the data recorder l.

[0026] Next, it “calculates a gain and a phase delay (phase difference) of the

system a by frequency from the gain (sound pressure) calibrating the microphones b and j on the basis of the calibration signal of the recorded data through the use of an analysis software in a personal computer m”.

[0027] Next, it “calculates a correction value data of the system a by frequency from the gain and the phase delay (phase difference) through the use of a spreadsheet software”.

[0028] Next, it “outputs the sweep sound from the sound source speaker i in the anechoic chamber n, and confirms that the gain (sound pressure) output from the control speaker f becomes an opposite phase to the gain (sound pressure) input to the system a”.

[0029] Next, it “outputs an actual sound (previously recorded actual noise) from the sound source speaker i in the anechoic chamber n, and confirms that a predetermined effect can be obtained in a gain level (sound pressure level) when the system a is turned on and off”.

[0030] In a case where the tuning operation is finished according to the above steps, the above-mentioned system a except the additional equipment is installed in the actual place.

[0031] Thereafter, it acquires the noise of the noise source by the reference microphone b to input to the system a, “outputs the control sound (actual sound) from the control speaker f, measures the sound pressure when the system a is turned on and off, and confirms the effect of the system a”.

[0032] In the tuning operation of the conventional active noise control system, it is necessary to prepare the other facilities and perform the tuning operation and a lot of additional devices are required since the tuning operation can not be performed by installing the system a in the actual place. As a result, the operation is extremely troublesome. Therefore, an improvement thereof is desired.

[0033] The present invention is made by taking into consideration the above-described conventional problem, and an object of the present invention is to provide an active noise control system with a tuning function which can easily perform a tuning operation, and a tuning method of the same.

SOLUTION TO PROBLEM

[0034] An active noise control system with a tuning function according to the present invention is provided with a reference microphone which acquires a noise issued from a noise source, a control controller which generates and outputs a control signal for reducing the noise input from the reference microphone, and a control speaker which emits a sound of the control signal output from the control controller, characterized in that the active noise control system is further provided with a tuning microphone which acquires a sound of an impulse signal output from the control speaker when tuning, that the control controller is provided with an impulse signal generating unit, a sound data processing unit, and a control unit, that the impulse signal generating unit executes a processing of generating the impulse signal, that the sound data processing unit is provided with a bandpass filter which is set by the control unit and allows only a frequency component in a predetermined frequency band to pass, an adaptive filter which is set by the control unit and estimates a predetermined dominant frequency on the basis of the frequency component passing through the bandpass filter, and an operation unit which is controlled by the control unit and executes at least a phase correction processing for the frequency input from the adaptive filter, that the control unit executes a processing of acquiring the sound data from the sound data processing unit, a processing of setting the bandpass filter and the adaptive filter, a processing of controlling the operation unit, and a processing of outputting the impulse signal from the impulse signal generating unit to the control speaker continuously more than once, that when tuning, the operation unit of the sound data processing unit executes a processing of calculating a correction amount of phase for every frequency and outputting to the control unit on the basis of a phase delay of an output for an input which is determined by the multiple impulse responses acquired by the tuning microphone, and the control unit executes a processing of setting the bandpass filter and the adaptive filter for correcting the phase delay, and that when active noise controlling, the bandpass filter of the sound data processing unit allows only a frequency component of a controlled object frequency band corresponding to the predetermined frequency band among

the noise input from the reference microphone to pass, the adaptive filter estimates a controlled object dominant frequency corresponding to the predetermined dominant frequency on the basis of the frequency component passing through the bandpass filter, and the operation unit performs a phase correction for the phase delay with respect to the controlled object dominant frequency input from the adaptive filter, and further executes a processing of generating the control signal of the opposite phase and outputting the control signal to the control speaker.

[0035] The active noise control system with the tuning function according to the present invention is further characterized in that the adaptive filter of the sound data processing unit is set by the control unit, and estimates the gain having the predetermined dominant frequency on the basis of the frequency component passing through the bandpass filter, that the operation unit of the sound data processing unit is controlled by the control unit, and executes a gain correction processing for the gain having the frequency input from the adaptive filter, that when tuning, the operation unit of the sound data processing unit executes a processing of calculating a correction amount of the phase and the gain for every frequency and outputting to the control unit on the basis of the phase delay and the gain of the output for the input determined by the multiple impulse responses acquired by the tuning microphone, and the control unit executes a processing of setting the bandpass filter and the adaptive filter for correcting the phase delay and the gain, and that when active noise controlling, the adaptive filter of the sound data processing unit estimates a controlled object dominant frequency corresponding to a predetermined dominant frequency and a gain thereof on the basis of the frequency component passing through the bandpass filter, and the operation unit performs a phase correction and a gain correction for the phase delay and the gain with respect to the controlled object dominant frequency input from the adaptive filter, and further executes a processing of generating a control signal having an opposite phase thereto and outputting the control signal to the control speaker.

[0036] A tuning method of an active noise control system with a tuning function according to the present invention is characterized in that the tuning

method uses the former active noise control system with the tuning function, that when tuning, the operation unit of the sound data processing unit executes the processing of calculating the correction amount of the phase for every frequency and outputting the correction amount to the control unit on the basis of the phase delay of the output for the input determined from the multiple impulse responses acquired by the tuning microphone, and that the control unit next executes the processing of setting the bandpass filter and the adaptive filter for correcting the phase delay.

[0037] A tuning method of an active noise control system with a tuning function according to the present invention is characterized in that the tuning method uses the latter active noise control system with the tuning function, that when tuning, the operation unit of the sound data processing unit executes the processing of calculating the correction amount of the phase and the gain for every frequency and outputting the correction amount to the control unit on the basis of the phase delay and the gain of the output for the input determined from the multiple impulse responses acquired by the tuning microphone, and that the control unit next executes the processing of setting the bandpass filter and the adaptive filter for correcting the phase delay and the gain.

EFFECT OF INVENTION

[0038] In the active noise control system with the tuning function and the tuning method of the same according to the present invention, the tuning operation can be easily performed.

BRIEF DESCRIPTION OF DRAWINGS

[0039] Fig. 1 is an explanatory view describing a preferable embodiment of an active noise control system with a tuning function according to the present invention.

Fig. 2 is a graph chart showing an example of an impulse response which is obtained when tuning the active noise control system in Fig. 1.

Fig. 3 is a graph chart showing a phase delay (phase frequency characteristic) and a gain (amplitude frequency characteristic) of an output for an input of the system, and a gain correction amount (gain correction frequency characteristic) for every frequency calculated by an operation unit, with regard to an example of a frequency characteristic shown in Fig. 2.

Fig. 4 is an explanatory view describing a correction method of the phase delay when active noise controlling the system shown in Fig. 1.

Fig. 5 is a flow chart describing a preferable embodiment of a tuning method of an active noise control system with a tuning function according to the present invention.

Fig. 6 is an explanatory view describing a state in which the conventional active noise control system is tuned by the other facilities.

Fig. 7 is a flow chart of a tuning operation when the conventional active noise control system is tuned by the other facilities.

DESCRIPTION OF EMBODIMENTS

[0040] A description will be in detail given below of preferable embodiments of an active noise control system with a tuning function and a tuning method of the same according to the present invention with reference to the accompanying drawings.

[0041] A description will be given of an active noise control system 1 (hereinafter, also refer simply to as “system”) with a tuning function according to the present embodiment, first with a focus on a system itself executing an inherent active noise control, with reference to Fig. 1.

[0042] The system 1 is configured to execute a feedforward control, and is constructed by a system reference microphone (hereinafter, refer simply to as reference microphone) 3 which acquires a noise issued from a noise source 2, a microphone amplifier 4 which amplifies an input signal input from the reference microphone 3 to output, a control controller 5 which processes a sound data input from the microphone amplifier 4 and outputs a control signal, a speaker amplifier 6 which amplifies the control signal output from the control controller 5 to output, and a control speaker 7 which emits an output signal

output from the speaker amplifier 6, that is, a sound (control sound) of the control signal output from the control controller 5.

[0043] Further, it is configured to generate a control sound having an opposite phase to the noise from the control speaker 7 with respect to the noise, thereby interfering and reducing the noise.

[0044] The control controller 5 is provided with a sound data processing unit 9, an impulse signal generating unit 8 which is embedded in the sound data processing unit 9, and a control unit 10.

[0045] The sound data processing unit 9 is constructed by an A/D converter 11 which converts an analogue signal input from the microphone amplifier 4 into a digital signal to output, a Fourier converter 12 which Fourier transforms the digital signal input from the A/D converter 11, a bandpass filter 13, an adaptive filter 14 and an operation unit 15 which process the digital signal of the sound data input from the Fourier converter 12 in series and are provided for generating and outputting a control signal for reducing the noise, and a D/A converter 16 which converts the digital signal output from the operation unit 15 into the analogue signal to output to the speaker amplifier 6.

[0046] The control unit 10 may be a personal computer which can be connected to and disconnected from the sound data processing unit 9.

[0047] Further, the control unit 10 is provided with a volume which adjusts a gain of the microphone amplifier 4 and the speaker amplifier 6 wired and connected to the control controller 5.

[0048] The present system 1 aims at selecting the noise having a frequency to be reduced among the noise including various frequency components and reducing the noise of the frequency.

[0049] The present embodiment targets at the dominant frequency, and the control controller 5 is configured to generate the control sound reducing the noise of the dominant frequency.

[0050] When operating the present system 1, a characteristic of the noise corresponding to the controlled object is preliminarily searched according to measurement and it is preliminarily considered what number of frequency of the noise is applied a sound absorbing control in conformity to the characteristic of the noise.

[0051] For example, in a construction machine such as a backhoe, an operating condition of an engine is different according to an idling state, a low load state, a middle load state and a high load state, and a characteristic (dominant frequency and sound pressure) of the issued noise is different in association with the difference. Therefore, the characteristic is preliminarily ascertained and the system 1 is set on the basis of the characteristic of the obtained noise.

[0052] The following description will be given of a case that the noise to be sound absorbed, that is, the controlled object frequency band is a low frequency band. Same applies to cases that the controlled object frequency band is a middle or high frequency band.

[0053] When active noise controlling, it is preferable to always make respective amounts of amplification for an input signal from the reference microphone 3 and an output signal from the D/A converter 16 constant, with regard to the microphone amplifier 4 and the speaker amplifier 6.

[0054] The A/D converter 11 converts an analogue signal (sound wave) from the reference microphone 3 into a digital signal (sound wave) according to a sampling frequency which is preliminarily set on the basis of the ascertained noise characteristic.

[0055] With regard to the sampling of the noise frequency, the sampling frequency is basically selected in a frequency range which is higher than twice a frequency to be measured (reproduced).

[0056] The output signal (digital signal) from the A/D converter 11 is input to the bandpass filter 13 of the sound data processing unit 9 in the control controller 5.

[0057] The bandpass filter 13 is set by the control unit 10 and allows only a frequency component in a predetermined frequency band to pass.

[0058] When active noise controlling, the bandpass filter 13 allows only a frequency component (sound) in a controlled object frequency band corresponding to a predetermined frequency band among the noise input from the reference microphone 3 to pass via the microphone amplifier 4, the A/D converter 11 and the Fourier converter 12.

[0059] More specifically, the bandpass filter 13 takes out the frequency

component near the dominant frequency to be sound absorbed with a cutoff frequency set by the control unit 10, and cuts signals of the other unnecessary frequency components.

[0060] Thus, the high frequency components higher than the controlled object frequency band and the low frequency components lower than the controlled object frequency band contained in the noise are removed, and the frequency components in the controlled object frequency band is taken out. The bandpass filter 13 is adjusted by a digital value, and is set to be changeable by the control unit 10.

[0061] In the bandpass filter 13, a phase delay is generated in the output signal relative to the input signal. The phase delay changes together with the change of frequency.

[0062] If the sound of the signal having the opposite phase to the signal passing through the bandpass filter 13 is emitted from the control speaker 7, it does not become the sound having the opposite phase to the noise.

[0063] In this case, the effect of reducing the noise is small, and the enlarged phase delay may amplify the noise.

[0064] Therefore, it is necessary to perform the phase correction of the output signal from the bandpass filter 13 for effectively reducing the noise.

[0065] In the bandpass filter 13, a phase characteristic (phase delay) for every frequency is known in a design stage. Although a description will be given later, a phase correction for the phase delay can be performed in the operation unit 15 relative to a frequency (controlled object dominant frequency) estimated by the adaptive filter 14 by utilizing the known phase characteristic (phase delay) for every frequency, in the bandpass filter 13.

[0066] The frequency component passing through the bandpass filter 13 is input to the adaptive filter 14 for executing the feedforward control.

[0067] The adaptive filter 14 of the sound data processing unit 9 is set by the control unit 10, and estimates a predetermined frequency and a gain thereof on the basis of the frequency component passing through the bandpass filter 13.

[0068] When active noise controlling, the adaptive filter 14 estimates the controlled object dominant frequency corresponding to the predetermined

frequency band on the basis of the low-frequency frequency component passing through the bandpass filter 13.

[0069] Further, the adaptive filter 14 estimates the gain (sound pressure) having the controlled object dominant frequency corresponding to the predetermined frequency band on the basis of the frequency component passing through the bandpass filter 13.

[0070] The adaptive filter 14 performs a frequency analysis using a step size parameter as well known.

[0071] More specifically, the adaptive filter 14 estimates the dominant frequency, that is, the dominant frequency coming to the controlled object when reducing the noise and the sound pressure thereof in a time domain on the basis of the step size parameter selected by an experiment such as a simulation.

[0072] The adaptive filter 14 is constructed by a replaceable data file, and is set to be selectively changeable by the control unit 10.

[0073] The estimation of the dominant frequency in the actual time of the adaptive filter 14 used for estimating the frequency of the low-frequency noise is important.

[0074] The application of the adaptive filter 14 estimates the frequency of the noise having the fluctuated frequency, thereby securing the effect of reducing the noise relative to the noise having the fluctuated frequency as described above.

[0075] The change of the frequency of the noise and the change of the maximum sound pressure in the passage of time are acquired from the noise which is obtained through the reference microphone 3 when active noise controlling, the frequency having the peak input sound pressure appears in the bandpass filter 13, and the frequency and the sound pressure of the noise coming to the controlled object is estimated using the adaptive filter 14 from the output of the bandpass filter 13.

[0076] The sound signal output from the adaptive filter 14 is input to the operation unit 15. The operation unit 15 is controlled by the control unit 10, and executes a phase correction processing and a gain correction processing relative to the frequency input from the adaptive filter 14 and the gain thereof.

[0077] When active noise controlling, the controlled object dominant frequency and the sound pressure thereof in the actual time estimated by the adaptive filter 14 are input to the operation unit 15.

[0078] The operation unit 15 performs the phase correction according to the time control for the phase delay relative to the controlled object dominant frequency input from the adaptive filter 14, further generates the control signal having the opposite phase thereto, and executes the processing of outputting the control sound having the opposite phase from the control speaker 7.

[0079] Further, the operation unit 15 generates the control signal having a gain correction for the gain (sound pressure) having the controlled object dominant frequency input from the adaptive filter 14.

[0080] The control unit 10 is configured to execute the processing of acquiring the sound data from the sound data processing unit 9 for controlling the sound data processing unit 9 as mentioned above, the processing of setting the bandpass filter 13 and the adaptive filter 14, and the processing of controlling the operation unit 15, and execute the processing of outputting the impulse signal from the impulse signal generating unit 8 provided in the control controller 5 to the control speaker 7 continuously more than once.

[0081] The present system 1 can not ascertain the phase delay and the gain difference (sound pressure difference) of the system 1 in the system 1 itself since the present system 1 does not use an error microphone as a given.

[0082] The present system 1 is structured such that the system 1 can correct the phase delay and the gain difference of the system without the error microphone. The point is in a function of the operation unit 15.

[0083] More specifically, through the use of the estimation of the dominant frequency of the noise performed in the adaptive filter 14, the operation unit 15 performs a processing such as a peculiar phase correction on the basis of a phase characteristic and a gain characteristic inherent in the system 1, corrects the phase delay and the gain of the control signal generated relative to the frequency extracted by the bandpass filter 13 and estimated by the adaptive filter 14, and thereafter outputs the control signal having the opposite phase.

[0084] As mentioned above, in the bandpass filter 13, the phase delay is

generated in the input signal and the output signal.

[0085] Therefore, as a whole of the control controller 5 including the bandpass filter 13, the phase delay is generated in the input signal and the output signal.

[0086] For generating the control sound having the opposite phase relative to the noise, it is necessary to perform the phase correction according to the time control and align the phase between the noise and the control sound.

[0087] With regard to the control speaker 7 and the reference microphone 3, it is necessary to consider that the gains thereof change depending on the frequency.

[0088] As is different from performing the phase correction and the gain correction for the phase delay and the gain on the basis of the construction of the system 1 by the other facilities such as the anechoic chamber according to the prior art, in order to perform the tuning operation of the system 1 in the actual place, the system 1 according to the present embodiment is provided with the impulse signal generating unit 8 which is disposed in the control controller 5 and executes the processing of generating the impulse signal, and the tuning microphone 17 which acquires the sound of the impulse signal generated by the impulse signal generating unit 8 and output from the control speaker 7.

[0089] The tuning microphone 17 is wired to the microphone amplifier 4 and is connected to the system 1.

[0090] In the tuning operation, the operation unit 15 calculates the phase delay and the gain inherent in the system 1, and an amount of phase correction and an amount of gain correction from the sound data acquired by the tuning microphone 17 through the use of the impulse response.

[0091] Each of the calculated correction amounts is input to the control unit 10, and the control unit 10 executes the processing of setting the bandpass filter 13 and the adaptive filter 14 on the basis of the amount of phase correction and the amount of gain correction from the operation unit 15 for correcting the phase delay and the gain.

[0092] The impulse response means an output from the system when the impulse is input to the system, as is well known.

[0093] In the system 1 according to the present embodiment, the operation unit 15 determines the phase delay and the gain of the output for the input of the system for every frequency on the basis of the multiple impulse responses as shown in Figs. 2 and 3, further calculates the amount of phase correction (phase frequency characteristic) and the amount of gain correction (gain correction frequency characteristic), and executes the processing of outputting to the control unit 10.

[0094] Fig. 3 shows a phase frequency characteristic and an amplitude frequency characteristic before correction, and a gain correction frequency characteristic after correction.

[0095] The phase delay and the gain for every frequency, and the amount of phase correction and the amount of gain correction are recorded in a storage area of the control unit 10.

[0096] The control unit 10 executes a processing of adjusting the setting of the bandpass filter 13 and the adaptive filter 14 when setting since the phase delay and the gain are at least affected by the bandpass filter 13 and the adaptive filter 14.

[0097] As a result, the phase and the gain are correctly set from the control controller 5 to the control speaker 7 according to the processing.

[0098] More specifically, in the system 1 according to the present embodiment, when tuning, the operation unit 15 of the sound data processing unit 9 executes the processing of calculating the correction amounts of the phase and the gain (amount of phase correction and amount of gain correction) for every frequency on the basis of the phase delay and the gain of the output for the input determined from the multiple impulse responses acquired in the tuning microphone 17 to output to the control unit 10, and the control unit 10 executes the processing of setting the bandpass filter 13 and the adaptive filter 14 for correcting the phase delay and the gain.

[0099] The tuning of the system 1 according to the present embodiment can be appropriately performed in the actual place since the sound source speaker is not installed while overlapped at the position of the noise source.

[0100] A method of phase correction for the phase delay performed by the operation unit 15 when active noise controlling with the present system 1 is as

follows (refer to Fig. 4).

[0101] In the drawing, a solid line shows the phase characteristic (sound pressure change) of the control controller 5, and a dashed line shows the phase characteristic (sound pressure change) of the controlled object dominant frequency estimated by the adaptive filter 14 from the output of the bandpass filter 13, that is, the true sound pressure. Reference symbol B denotes a control start time, reference sign M denotes a sound pressure value of the control controller 5 at the control start time B, and reference sign R denotes a true sound pressure value at the control start time B.

(1) Determine a data number N of one wavelength (wave for one cycle; range between A and B) of the controlled object dominant frequency estimated by the adaptive filter 14 on the basis of hours for control.

(2) Store a waveform data (waveform expressed by the data number N) for one wavelength (one cycle) determined as mentioned above from the control start time B.

(3) Determine a phase delay ϕ (rad) of the control controller 5 for the controlled object dominant frequency estimated by the adaptive filter 14.

(4) Determine a data number N_p corresponding to the phase delay. ($N_p = N \times (\phi/2\pi)$)

(5) Determine a data number N_x obtained by subtracting the data number N_p corresponding to the phase delay from the data N for one wavelength (one cycle).

(6) Take out the subtracted data number N_x from the stored waveform data for one wavelength retroactively beginning at the control start time B, and determine a phase corrected sound pressure (phase) H at this position as an inherent sound pressure (phase) R. This is based on the fact that the wave phase is repeated at 0 to 2π .

[0102] The operation unit 15 further generates a control signal by performing a processing of setting the phase corrected waveform to an opposite phase.

[0103] The generated control signal is output from the operation unit 15 of the control controller 5. The output sound pressure is set to a value obtained by multiplying the estimated sound pressure by an amplification.

[0104] A digital signal of the control signal output from the control controller 5

is converted into an analogue signal by the D/A converter 16.

[0105] The output signal (analogue signal) of the control signal output from the D/A converter 16 is input to the speaker amplifier 6 to be amplified.

[0106] The sound of the amplified control signal output from the speaker amplifier 6 is emitted from the control speaker 7.

[0107] In the system 1 according to the present embodiment, without using an error microphone and with the use of the estimation of the noise dominant frequency performed by the adaptive filter 14, the operation unit 15 performs the processing such as the peculiar phase correction on the basis of the result of tuning operation, corrects the phase difference and the sound pressure ratio of the generated control sound relative to the frequency extracted by the bandpass filter 13, and thereafter output the control signal having the opposite phase.

[0108] A tuning method of the active noise control system 1 with the tuning function according to the present embodiment installs the system shown in Fig. 1 in the actual place.

[0109] The tuning microphone 17 is connected to the microphone amplifier 4 only when tuning. The reference microphone 3 is not used for the tuning operation.

[0110] An execution procedure of the tuning of the present system first “inputs and stores a parameter of the bandpass filter 13” in the control unit 10 as shown in Fig. 6.

[0111] Next, it performs “volume adjustment of the control speaker 7 for the object sound (noise)” relative to the speaker amplifier 6 by the control unit 10.

[0112] Next, when the impulse signal is generated by the impulse signal generating unit 8 and is output from the control speaker 7 in the control unit 10, the operation unit 15 of the sound data processing unit 9 executes the processing of calculating the correction amounts of the phase and the gain every frequency on the basis of the phase delay and the gain of the output for the input determined from the multiple impulse responses acquired by the tuning microphone 17 and outputting the correction amounts to the control unit 10.

[0113] Next, the control unit 10 executes the processing of setting the

bandpass filter 13 and the adaptive filter 14 for correcting the phase delay and the gain.

[0114] More specifically, there is performed a series of processing of “measuring the gain and the phase difference (phase delay) of the system 1 on the basis of the impulse response, automatically calculating the gain correction value and the phase correction value by the operation unit 15 and storing in the control unit 10”, by outputting the sound of the impulse signal from the control speaker 7.

[0115] Next, it performs “inputting the parameter data of the adaptive filter 14 to the control unit 10 and storing it in the control unit 10”.

[0016] It is possible to correct the phase delay and the gain inherent in the system 1 by performing the tuning operation mentioned above.

[0017] After the tuning operation, the tuning microphone 17 is disconnected from the microphone amplifier 4.

[0118] When active noise controlling after the end of the tuning operation, the noise issued from the noise source 2 is acquired by the reference microphone 3.

[0119] The noise measured by the reference microphone 3 is input to the bandpass filter 13, the adaptive filter 14 estimates the controlled object dominant frequency in the time domain from the output of the bandpass filter 13, and the operation unit 15 corrects the phase and the sound pressure and generates the sound having the opposite phase to the corrected wave component. As a result, the noise can be reduced.

[0120] Particularly, the bandpass filter 13 of the sound data processing unit 9 allows only the frequency component of the controlled object frequency band corresponding to the predetermined frequency band among the noise input from the reference microphone 3 to pass, the adaptive filter 14 of the sound data processing unit 9 estimates the controlled object dominant frequency corresponding to the predetermined dominant frequency and the gain thereof on the basis of the frequency component passing through the bandpass filter 13, the operation unit 15 performs the phase correction and the gain correction for the phase delay and the gain with respect to the controlled object dominant frequency input from the adaptive filter 14, and further

executes the processing of generating the control signal having the opposite phase thereto and outputting the control signal to the control speaker 7.

[0121] At this time, in a case where the reference microphone 3 is installed at a little distance from the noise source 2, for example, for the reason of the noise source 2 being close to the heat source, it is possible to execute a processing of “adjusting according to a fine adjustment function of the gain by the volume of the speaker amplifier 6 provided in the control unit 10 and the phase of the bandpass filter 13 by the control unit 10 so as to obtain a predetermined sound absorbing effect while confirming the sound pressure level when turning on the control (active noise controlling) relative to the noise corresponding to the actual sound”.

[0122] In the active noise control system 1 with the tuning function and the tuning method of the same according to the present embodiment described above, the sound of the impulse signal from the impulse signal generating unit 8 provided in the system 1 is emitted from the control speaker 7, the sound of the impulse signal is acquired by the tuning microphone 17 and is input to the system 1, the amount of phase correction and the amount of gain correction are calculated for every frequency on the basis of the phase delay and the gain of the output for the input determined from the multiple impulse responses in the operation unit 15 of the system 1, and the control unit 10 executes the processing of setting the bandpass filter 13 and the adaptive filter 14 on the basis of the calculated amount of phase correction and the calculated amount of gain correction. Therefore, the tuning operation can be extremely easily performed in comparison with the prior art.

[0123] Particularly, in the tuning operation according to the prior art, it is physically impossible to install the sound source speaker as the sound source for tuning while overlapping at the position of the noise source. Therefore, the tuning operation can not be performed in the actual place, and it is necessary to prepare the other facilities and perform the tuning operation, so that it takes a lot of trouble over the preparation for the tuning operation and the tuning operation is troublesome.

[0124] Further, various kinds of unnecessary additional equipment have to be frequently used for the tuning operation inconveniently when active noise

controlling.

[0125] On the contrary, in the system 1 with the tuning function and the tuning method of the same according to the present embodiment, the sound of the impulse signal is configured to be output from the control speaker 7 and be acquired by the tuning microphone 17 in place of the use of the sound source speaker, and the sound source speaker is not required. Therefore, the tuning operation can be performed in the actual place.

[0126] Further, in the tuning operation, the impulse signal corresponding to a momentary sound generated within the system 1 is configured to be used and be acquired by the tuning microphone 17. Therefore, it is possible to appropriately perform the tuning operation without being affected by the surrounding noise of the actual place.

[0127] Further, in the present embodiment, the control controller 5 is provided with the impulse signal generating unit 8, and it is enough just to prepare the tuning microphone 17 which is also used in the prior art, as the additional equipment, and any other additional equipment is not required. Thus, it is possible to extremely simplify an installing work and a tuning procedure, and the tuning operation can be easily performed.

[0128] In the prior art, in a case where a partial equipment of the system crashes due to a life span, it is necessary to once bring back all the system to replace the crashed equipment and return the equipment to the actual place after applying re-tuning. However, in the system 1 according to the present embodiment, it is sufficient to replace the crashed equipment on the scene and apply the re-tuning. As a result, it is possible to widely reduce the labor hour.

REFERENCE SIGNS LIST

[0129] 1 active noise control system with tuning function

2 noise source

3 reference microphone of system

5 control controller

7 control speaker

8 impulse signal generating unit
9 sound data processing unit
10 control unit
13 bandpass filter
14 adaptive filter
15 operation unit
17 tuning microphone

CLAIMS

1. An active noise control system with a tuning function comprising:
 - a reference microphone which acquires a noise issued from a noise source;
 - a control controller which generates and outputs a control signal for reducing the noise input from the reference microphone; and
 - a control speaker which emits a sound of the control signal output from the control controller,wherein the active noise control system further includes a tuning microphone which acquires a sound of an impulse signal output from the control speaker when tuning,
 - wherein the control controller includes an impulse signal generating unit, a sound data processing unit, and a control unit,
 - wherein the impulse signal generating unit executes a processing of generating the impulse signal,
 - wherein the sound data processing unit includes a bandpass filter which is set by the control unit and allows only a frequency component in a predetermined frequency band to pass, an adaptive filter which is set by the control unit and estimates a predetermined dominant frequency on the basis of the frequency component passing through the bandpass filter, and an operation unit which is controlled by the control unit and executes at least a phase correction processing for the frequency input from the adaptive filter,
 - wherein the control unit executes a processing of acquiring the sound data from the sound data processing unit, a processing of setting the bandpass filter and the adaptive filter, a processing of controlling the operation unit, and a processing of outputting the impulse signal from the impulse signal generating unit to the control speaker continuously more than once,
 - wherein when tuning,
 - the operation unit of the sound data processing unit executes a processing of calculating a correction amount of phase for every frequency and outputting to the control unit on the basis of a phase delay of an output for

an input which is determined by the multiple impulse responses acquired by the tuning microphone, and

the control unit executes a processing of setting the bandpass filter and the adaptive filter for correcting the phase delay, and

wherein when active noise controlling,

the bandpass filter of the sound data processing unit allows only a frequency component of a controlled object frequency band corresponding to the predetermined frequency band among the noise input from the reference microphone to pass,

the adaptive filter estimates a controlled object dominant frequency corresponding to the predetermined dominant frequency on the basis of the frequency component passing through the bandpass filter, and

the operation unit performs a phase correction for the phase delay with respect to the controlled object dominant frequency input from the adaptive filter, and further executes a processing of generating the control signal of the opposite phase and outputting the control signal to the control speaker.

2. The active noise control system with the tuning function according to claim 1, wherein the adaptive filter of the sound data processing unit is set by the control unit, and estimates the gain having the predetermined dominant frequency on the basis of the frequency component passing through the bandpass filter,

wherein the operation unit of the sound data processing unit is controlled by the control unit, and executes a gain correction processing for the gain having the frequency input from the adaptive filter,

wherein when tuning,

the operation unit of the sound data processing unit executes a processing of calculating a correction amount of the phase and the gain for every frequency and outputting to the control unit on the basis of the phase delay and the gain of the output for the input determined by the multiple impulse responses acquired by the tuning microphone, and

the control unit executes a processing of setting the bandpass filter

and the adaptive filter for correcting the phase delay and the gain, and
wherein when active noise controlling,

the adaptive filter of the sound data processing unit estimates a controlled object dominant frequency corresponding to a predetermined dominant frequency and a gain thereof on the basis of the frequency component passing through the bandpass filter, and

the operation unit performs a phase correction and a gain correction for the phase delay and the gain with respect to the controlled object dominant frequency input from the adaptive filter, and further executes a processing of generating a control signal having an opposite phase thereto and outputting the control signal to the control speaker.

3. A tuning method of an active noise control system with a tuning function, wherein the tuning method uses the active noise control system with the tuning function according to claim 1,

wherein when tuning,

the operation unit of the sound data processing unit executes the processing of calculating the correction amount of the phase for every frequency and outputting the correction amount to the control unit on the basis of the phase delay of the output for the input determined from the multiple impulse responses acquired by the tuning microphone, and

the control unit next executes the processing of setting the bandpass filter and the adaptive filter for correcting the phase delay.

4. A tuning method of an active noise control system with a tuning function, wherein the tuning method uses the active noise control system with the tuning function according to claim 2,

wherein when tuning,

the operation unit of the sound data processing unit executes the processing of calculating the correction amount of the phase and the gain for every frequency and outputting the correction amount to the control unit on the basis of the phase delay and the gain of the output for the input determined from the multiple impulse responses acquired by the tuning

microphone, and

the control unit next executes the processing of setting the bandpass filter and the adaptive filter for correcting the phase delay and the gain.