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(54) **NOISE CONTROL SYSTEM FOR WASHING MACHINE AND WASHING MACHINE**

(57) A noise control system for a washing machine and a washing machine are provided. The system includes: a first acquisition unit, configured to acquire a first vibration signal of a first vibration of a motor; a second acquisition unit, configured to acquire a rotational speed signal of the motor; a control unit, configured to receive the first vibration signal transmitted by the first acquisition unit and the rotational speed signal transmitted by the second acquisition unit, and process the first vibration signal and the rotational speed signal to generate a control signal; and an execution unit, configured to receive the control signal, and generate, based on the control signal, a second vibration acting on the motor.

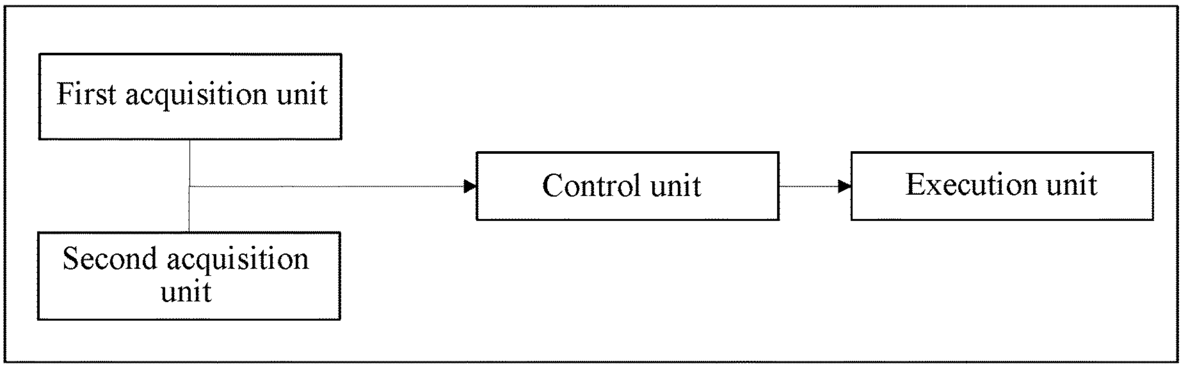

FIG. 2

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Description

TECHNICAL FIELD

[0001] The utility model relates to the technical field of household appliances, and in particular, to a noise control system for a washing machine and a washing machine.

BACKGROUND

[0002] As washing machine technologies continuously develop, washing machines can realize increasing functions and have an increasing washing capacity and an increasing dehydration speed. Although convenience is brought to user's life, problems regarding vibration and noise are becoming prominent. Excessive noise affects people's life, even their health.

[0003] Most of the current washing machines on the market are drum washing machines. In a general structure of the drum washing machines, a drum is mounted to an external case through springs and dampers, and a motor is rigidly mounted to the drum. The motor is connected to the drum by a belt. A transmission ratio of the belt is generally 10:1. If a maximum rotational speed of the drum during dehydration is 1400 RPM, a rotational speed of the motor is at least 14000 RPM. Even a small unbalanced mass of a rotor of the motor will lead to relatively large vibration. A frequency of the vibration is a first-order rotating frequency. The first-order vibration eventually leads to first-order pitch noise of the whole machine. Moreover, the rotor that drives the motor is supported in a bearing chamber through two rolling bearings. Each of the rolling bearings has a specific component characteristic frequency, such as a bearing inner race passing frequency and a bearing outer race passing frequency. During dehydration in the washing machine, a rotational speed of the motor increases from 0 to the highest rotational speed. When a frequency of an excitation force is the same as the bearing characteristic frequency, resonance is caused, which radiates single frequency noise.

[0004] The first-order noise and the single frequency noise corresponding to the bearing characteristic frequency lead to relatively large noise of the whole machine. In some cases, even if a noise value of the whole machine is not high, the prominent single frequency noise will significantly degrade the sound quality of the whole machine, resulting in acoustic discomfort to users. Therefore, the noise needs to be reduced.

[0005] There is no essential difference in vibration and noise reduction principles between washing machines and other devices. Passive noise reduction and active noise reduction methods are frequently used. Currently, passive noise reduction and active noise reduction are both performed after noise is generated and before the noise is transmitted to human ears, which lack corresponding measures before the noise is radiated, that is, lack vibration and noise reduction at an excitation source.

[0006] Currently, the existing technology has no technical solution for the above technical problem.

SUMMARY

[0007] In order to resolve at least the above problem, the utility model provides a noise control system for a washing machine. The washing machine includes a washing machine case, a drum arranged in the washing machine case, and a motor configured to drive the drum to rotate. The system includes: a first acquisition unit, configured to acquire a first vibration signal of a first vibration of a motor; a second acquisition unit, configured to acquire a rotational speed signal of the motor; a control unit, configured to receive the first vibration signal transmitted by the first acquisition unit and the rotational speed signal transmitted by the second acquisition unit, and process the first vibration signal and the rotational speed signal to generate a control signal; and an execution unit, configured to receive the control signal, and generate, based on the control signal, a second vibration acting on the motor. The first vibration is opposite to the second vibration in phase to offset the first vibration of the motor, so as to reduce excitation forces transmitted to the drum and the washing machine case through the motor.

[0008] Active control is performed on a vibration excitation source in this way, that is, vibration control is performed on a source of noise, to reduce excitation forces transmitted to the drum and the case, thereby realizing vibration and noise reduction, especially reduction of noise generated during high-speed dehydration.

[0009] Further, for active noise reduction, an active noise reduction system collects noise signals, which is vulnerable to external interference. In particular, for low-frequency noise, the system is complex and is unstable. The noise control system in this solution collects vibration signals, and focuses on reduction of medium and low frequency vibrations, which is less affected by external interference, and has a relatively simple system design and is stable.

[0010] Further, the noise control system can further significantly reduce first-order noise caused by an unbalanced mass of a rotor of the motor. Therefore, a relatively large unbalanced mass is allowed for the rotor of the motor, facilitating the control during production.

[0011] In addition, the noise control system can further significantly reduce single frequency noise caused by a characteristic frequency of a rolling bearing of the motor. Therefore, in a motor design process, bearings may be selected more freely, instead of selecting specified bearings for resolving problems regarding noise.

[0012] In a possible embodiment, the control signal includes a second vibration signal. The execution unit generates a corresponding second vibration according to the second vibration signal, so that the execution unit generates a corresponding damping force wave to reduce or even offset the vibration generated by the motor.

[0013] In a possible embodiment, a mounting position of the first acquisition unit is associated with a vibration direction of the motor, to acquire the first vibration signal of the motor in the corresponding vibration direction through the first acquisition unit. For example, the first acquisition unit acquires first vibration signals in three directions of the motor perpendicular to each other. The vibrations of the motor in different directions are acquired through the first acquisition unit, so as to control the vibrations of the motor in the plurality of directions through the control unit and the execution unit, thereby alleviating the noise of the washing machine system more effectively and improving the sound quality of the whole machine.

[0014] The motor includes a motor end cover, and the first acquisition unit is arranged on the motor end cover, to help collect more precise vibration signals of the motor.

[0015] The first acquisition unit includes a vibration sensor. The noise control system in this solution collects the vibration signals through the vibration sensor, and focuses on reduction of medium and low frequency vibration, which is less affected by external interference, and has a relatively simple system design and is stable.

[0016] In a possible embodiment, the execution unit is mounted in the three directions of the motor, and the execution units is configured to generate corresponding second vibrations in the three directions based on the first vibrations in the three directions. For example, the execution unit includes an exciter and is rigidly connected to the motor. The vibrations of the motor in the plurality of directions are controlled through the control unit and the execution unit, so as to alleviate the noise of the washing machine system more effectively and improve the sound quality of the whole machine.

[0017] In a possible embodiment, the exciter is fixed on a surface of the motor, so that vibration generated by the exciter directly acts on the motor, thus resolving the noise problem of the washing machine at the source of noise.

[0018] In a possible embodiment, the second acquisition unit includes a rotational speed sensor arranged on the washing machine drum, which may be configured to collect the rotational speed signal of the motor.

[0019] In a possible embodiment, the control unit is arranged on an inner wall of the washing machine case, or may be integrated with a control module of the washing machine.

[0020] A washing machine is provided, including a washing machine case, a drum arranged inside the washing machine case, and a motor connected to the drum and configured to drive the drum to rotate. The washing machine further includes the noise control system for a washing machine described above. During operation of the washing machine, especially during high-speed dehydration, the noise control system performs active control on the vibration excitation source, that is, performs vibration control on the source of noise, to reduce excitation forces transmitted from the motor to the drum and the case, thereby realizing vibration and noise reduction. In particular, narrow band noise caused by resonance can be significantly reduced, a noise value can be reduced, and the sound quality can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a brief schematic structural diagram of a washing machine according to an embodiment of the utility model.

FIG. 2 is a logic block diagram of a noise control system for a washing machine according to an embodiment of the utility model.

FIG. 3 is a schematic principle diagram of the noise control system for a washing machine in FIG. 2.

DETAILED DESCRIPTION

[0022] FIG. 1 shows a simple structure of a washing machine. The washing machine 1 includes a washing machine case 10 and a drum 20 arranged in the washing machine case 10. The drum 20 is connected to the washing machine case 10 through a support member 70. The support member 70 may be an elastic member, for example, may be a spring arranged at an upper position of the drum 20 for lifting the drum 20, or may be a damper arranged at a lower position of the drum 20 for supporting the drum 20 from below.

[0023] The washing machine 1 further includes a motor 30 for driving the drum 20 to rotate. The motor 30 is connected to the drum 20. The motor 30 may be connected to the drum 20 by directly connecting a motor shaft to the drum 20, to drive the drum 20 to rotate. Alternatively, the drum 20 may be driven to rotate through belt transmission or in other transmission manners. This is not limited herein.

[0024] Generally, the washing machine generates noise during operation, especially during dehydration. A part of the noise results from a rotor of the motor. An unbalanced mass of rotor of the motor leads to a relatively large vibration. A frequency of the vibration is a first-order rotating frequency. The first-order vibration eventually leads to first-order pitch noise of the whole machine. Other part of the noise results from resonance of the machine. Specifically, the rotor of the motor is supported in a bearing chamber through two rolling bearings. Each of the rolling bearings has a specific component characteristic frequency, such as a bearing inner race passing frequency and a bearing outer race passing frequency. During dehydration in the washing machine, a rotational speed of the motor increases from 0 to the highest rotational speed. When a frequency of an excitation force is the same as the bearing characteristic frequency, resonance is caused, which radiates single frequency noise.

[0025] The first-order noise and the single frequency noise corresponding to the bearing characteristic frequency lead to relatively large noise of the whole machine. In some cases, even if a noise value of the whole machine is not high, the prominent single frequency noise will significantly degrade the sound quality of the whole machine, resulting in acoustic discomfort to users. Therefore, the noise needs to be reduced.

[0026] In order to resolve the above problem, an embodiment of the present invention further provides a noise control system for the above washing machine. Specifically, with reference to FIG. 1 and FIG. 2, the washing machine further includes a noise control system 2, including:

- a first acquisition unit, configured to acquire a first vibration signal of a first vibration of the motor 30;
- a second acquisition unit, configured to acquire a rotational speed signal of the motor 30;
- a control unit, configured to receive the first vibration signal transmitted by the first acquisition unit and the rotational speed signal transmitted by the second acquisition unit, and process the first vibration signal and the rotational speed signal to generate a control signal; and
- an execution unit, configured to receive the control signal, and generate, based on the control signal, a second vibration acting on the motor 30, where the first vibration is opposite to the second vibration in phase to offset the first vibration of the motor 30, so as to reduce excitation forces transmitted to the drum 20 and the washing machine case 10 through the motor 30.

[0027] In the above solution, active vibration reduction is performed. Active control is performed on a vibration excitation source, that is, vibration control is performed a source of noise, to reduce the excitation forces transmitted to the drum and the case, thereby realizing vibration and noise reduction, especially reduction of noise generated during high-speed dehydration.

[0028] Further, the noise control system is mainly configured to reduce a narrow band vibration generated by the motor during the dehydration in the washing machine, so as to reduce the single frequency noise during the dehydration, for example, single frequency vibrations corresponding to a first-order rotating frequency (rotational speed/60), a second-order rotating frequency, and a bearing characteristic frequency.

[0029] Specifically, the noise control system can significantly reduce first-order noise caused by the unbalanced mass of the rotor of the motor. Therefore, a relatively large unbalanced mass is allowed for the rotor of the motor, facilitating the control during production. In addition, the noise control system can significantly reduce single frequency noise caused by a characteristic frequency of a rolling bearing of the motor. Therefore, in a motor design process, bearings may be selected more freely, instead of selecting specified bearings for resolving problems regarding noise.

[0030] Further, the noise control system realizes significant noise reduction effects for medium and low frequency vibration, while passive noise reduction measures realize merely limited noise reduction effects for medium and low frequency noise. For active noise reduction, a mounting position of a secondary sound source needs to be spaced apart from a primary sound source by a specified wavelength distance. Since medium and low frequency noise has a relatively large sound wavelength, the secondary sound source needs to be mounted relatively far away from the primary sound source, and an actual internal space of the washing machine is limited, the mounting cannot be realized.

[0031] Detailed description is provided below with reference to FIG. 1 and FIG. 2.

[0032] The noise control system includes a first acquisition unit, a second acquisition unit, a control unit, and an execution unit. The first acquisition unit may be a vibration sensor 40, and may be arranged on the end cover of the motor 30. For example, the vibration sensor 40 is a piezoelectric acceleration sensor or other types of sensors, which is fixed on the end cover of the motor through threaded connection.

[0033] In an embodiment, a mounting position of the vibration sensor 40 is associated with a vibration direction of the motor 30, to acquire the first vibration signal of the motor in the corresponding vibration direction through the vibration sensor 40.

[0034] Further, the motor 30 may vibrate in three directions perpendicular to each other in a space, and the vibration sensor 40 may acquire first vibration signals of the motor 30 in the three directions perpendicular to each other.

[0035] The second acquisition unit may include a rotational speed sensor 80 (not shown). The rotational speed sensor is not necessary for the system, and the rotational speed signal may be acquired from a motor control unit integrated in the washing machine. If the signal cannot be acquired, an additional rotational speed sensor needs to be mounted. The rotational speed sensor is a photoelectric or laser sensor, and may be mounted to the drum 20 of the washing machine to collect the rotational speed signal.

[0036] A control unit 60 may be fixed on the washing machine case 10, as shown in FIG. 1, or may be integrated with a control module of the washing machine.

[0037] The execution unit includes an exciter 50 and is rigidly connected to the motor 30. The exciter 50 may be an electric exciter rigidly fixed on a surface of the motor 30.

[0038] In an embodiment, the exciter 50 may be correspondingly mounted in each of the three directions of the motor 30.

[0039] The exciter 50 is configured to generate corresponding second vibrations in the three directions based on the first vibrations in the three directions.

[0040] For example, the motor 30 vibrates in three directions: X, Y, and Z. A first-order vibration is perpendicular to the direction Y of an axis of the motor, and resonance caused by the bearing characteristic frequency may be in the axial direction Z or the vertical direction X. Therefore, if vibration reduction is required for a plurality of vibration directions, a plurality of vibration sensors and exciters need to be mounted in the corresponding directions, but noise control algorithms for the different directions are the same. However, for a plurality of different single frequency vibrations in the same direction, only one vibration sensor and one exciter are required.

[0041] Arranging the vibration sensor 40 and the exciter 50 in the different vibration directions of the motor realizing control for vibration and noise reduction in the plurality of corresponding directions, which significantly improves the sound quality of the whole machine.

[0042] In an embodiment, the control unit may acquire the signals of the vibration sensor 40 and the rotational speed sensor 80, and process and analyze the first vibration signal and the rotational speed signal by using the control algorithm to generate a control signal. The control signal includes a second vibration signal, and the exciter 50 may generate a corresponding second vibration according to the second vibration signal to offset the first vibration of the motor 30, thereby reducing the excitation forces transmitted to the drum 20 and the washing machine case 10 through the motor 30.

[0043] The control algorithm of the noise control system may include feedforward control, feedback control, a hybrid control algorithm, and the like.

[0044] FIG. 3 is a principle diagram of the noise control system for the washing machine.

[0045] Specifically, with reference to FIG. 3, a working process of the noise control system is as follows:
The vibration sensor 40 is usually mounted to the motor 30. When the washing machine 1 starts working, the excitation force of the motor 30 acts on the washing machine 1. The vibration sensor 40 acquires a residual vibration signal of the washing machine 1 in real time, especially after vibration reduction of the motor 30, that is, acquires the first vibration signal of the first vibration of the motor 30, which includes a vibration frequency, an amplitude, and a phase. In addition, the rotational speed signal of the motor 30 is acquired through the control unit 60 of the motor 30 or the rotational speed sensor 80.

[0046] The vibration sensor 40 and the rotational speed sensor 80 transmit the collected residual vibration signal and rotational speed signal to the control unit 60 in real time, and the control unit analyzes and processes the signals according to the algorithm integrated therein.

[0047] The control unit 60 outputs the processed control signal to the exciter 50. The control signal includes a frequency, an amplitude, and a phase of a to-be-generated signal.

[0048] The exciter 50 transmits a damping force wave with the same frequency and the same amplitude as the first vibration signal and the opposite phase to the first vibration signal according to the control signal, that is, generates the second vibration to offset the first vibration generated by the motor 30.

[0049] The control unit 60 adjusts, according to the residual vibration signals that are fed back, the damping force wave outputted in real time, to achieve more effective vibration and noise reduction.

[0050] In the above solution, active control is performed a vibration excitation source, to reduce the excitation forces transmitted to the drum and the case, so as to realize vibration and noise reduction, thereby improving the sound quality of the whole machine.

[0051] The foregoing descriptions are merely specific implementations of the utility mode, but are not intended to limit the protection scope of the utility mode. Any equivalent modification or replacement readily figured out by a person skilled in the art within the technical scope disclosed in the utility model shall fall within the protection scope of the utility model. Therefore, the protection scope of the utility mode shall be subject to the protection scope of the claims.

Claims

1. A noise control system for a washing machine, the washing machine comprising a washing machine case, a drum arranged in the washing machine case, and a motor configured to drive the drum to rotate, **characterized in that** the system comprises:

   a first acquisition unit, configured to acquire a first vibration signal of a first vibration of the motor;
   a second acquisition unit, configured to acquire a rotational speed signal of the motor;
   a control unit, configured to receive the first vibration signal transmitted by the first acquisition unit and the rotational speed signal transmitted by the second acquisition unit, and process the first vibration signal and the rotational speed signal to generate a control signal; and
   an execution unit, configured to receive the control signal, and generate, based on the control signal, a second vibration acting on the motor, wherein the first vibration is opposite to the second vibration in phase to offset the first vibration of the motor, so as to reduce excitation forces transmitted to the drum and the washing machine case through the motor.

2. The system according to claim 1, **characterized in that** the control signal comprises a second vibration signal, and the execution unit generates the corresponding second vibration according to the second vibration signal.

3. The system according to claims 1 or 2, **characterized in that** a mounting position of the first acquisition unit is associated with a vibration direction of the motor, to acquire the first vibration signal of the motor in the corresponding vibration direction through the

first acquisition unit.

4. The system according to any of the preceding claims, **characterized in that** the first acquisition unit acquires first vibration signals in three directions of the motor perpendicular to each other.

5. The system according to any of the preceding claims, **characterized in that** the motor comprises a motor end cover, and the first acquisition unit is arranged on the motor end cover.

6. The system according to any of the preceding claims, **characterized in that** the first acquisition unit comprises a vibration sensor.

7. The system according to any of the preceding claims, **characterized in that** the execution unit is mounted in each of the three directions of the motor, and the execution unit is configured to generate corresponding second vibrations in the three directions based on the first vibrations in the three directions.

8. The system according to any of the preceding claims, **characterized in that** the execution unit comprises an exciter and is rigidly connected to the motor.

9. The system according to any of the preceding claims, **characterized in that** the exciter is fixed on a surface of the motor.

10. The system according to any of the preceding claims, **characterized in that** the second acquisition unit comprises a rotational speed sensor arranged on the washing machine drum.

11. The system according to any of the preceding claims, **characterized in that** the control unit is arranged on an inner wall of the washing machine case.

12. A washing machine, comprising a washing machine case, a drum arranged inside the washing machine case, and a motor connected to the drum and configured to drive the drum to rotate, **characterized in that** the washing machine further comprises the noise control system for a washing machine according to any of claims 1 to 11.

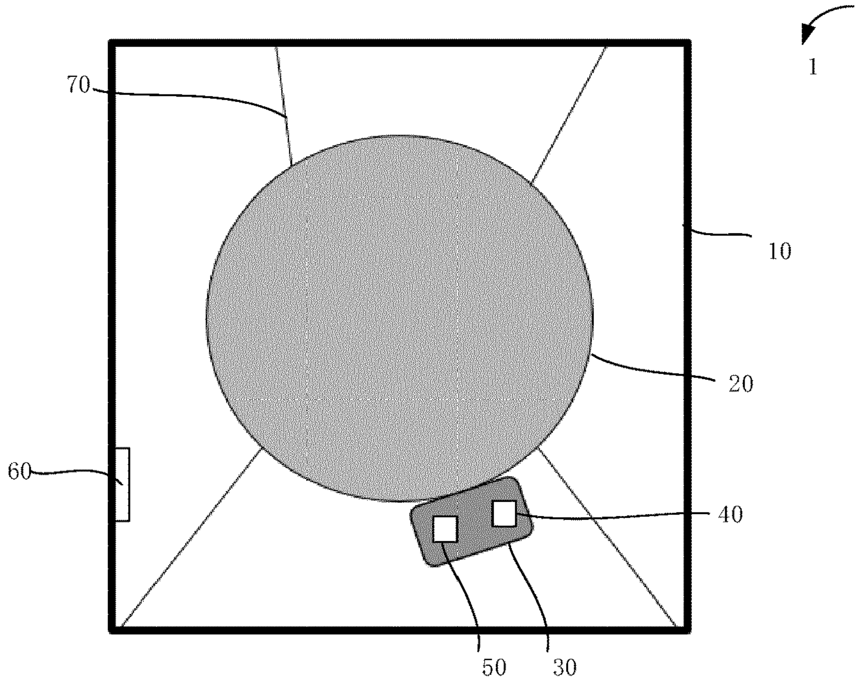
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FIG. 1

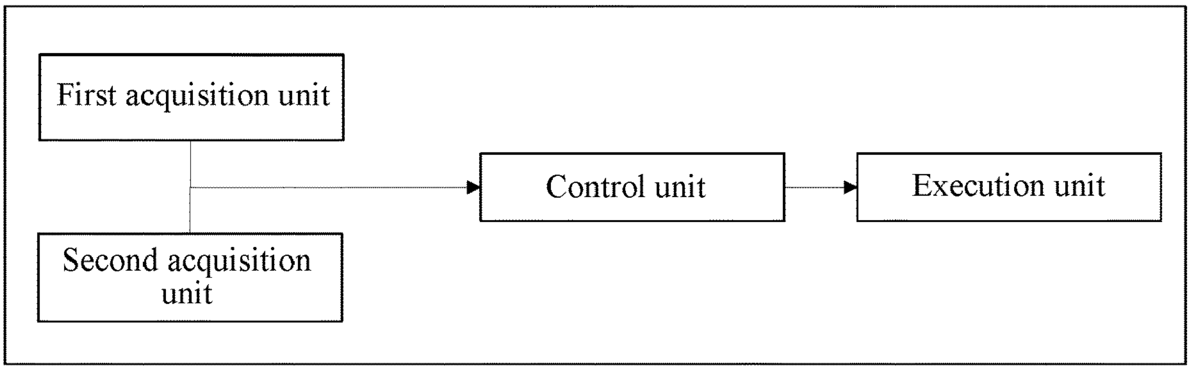
First acquisition unit
Second acquisition unit
Control unit
Execution unit

FIG. 2

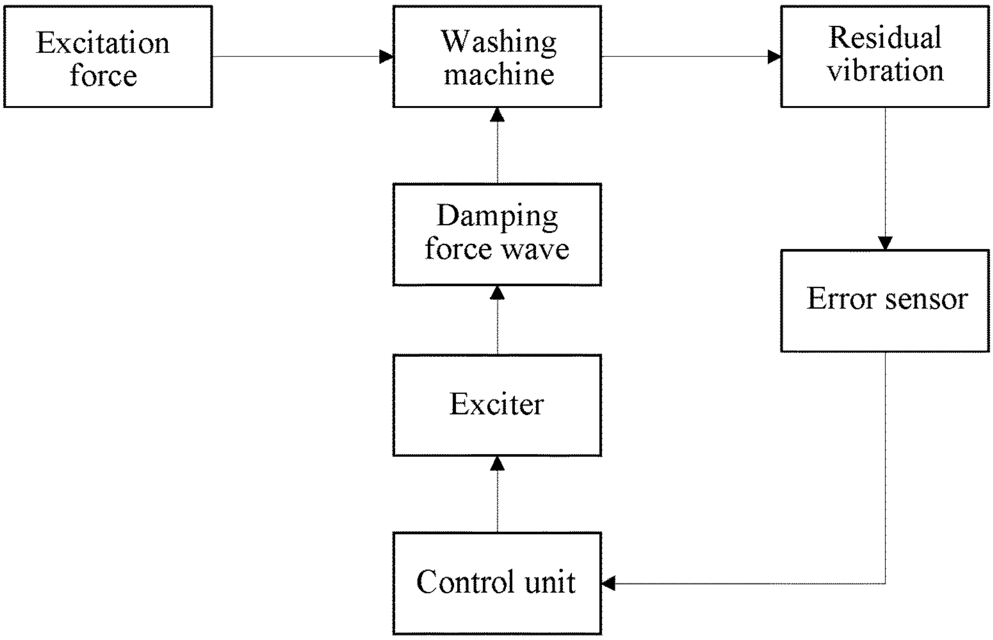
Excitation force
Washing machine
Residual vibration
Damping force wave
Error sensor
Exciter
Control unit

FIG. 3

EUROPEAN SEARCH REPORT

Application Number
EP 22 20 8295

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	JP H07 323193 A (SANYO ELECTRIC CO) 12 December 1995 (1995-12-12) * the whole document * -----	1-12	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 April 2023	Diaz y Diaz-Caneja

CATEGORY OF CITED DOCUMENTS

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EP 22 20 8295

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