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(54) METHOD FOR NATURAL FREQUENCY DETECTION IN A DRUM WASHING MACHINE

(57) The proposed invention relates to a method for detecting the natural vibration frequencies in the body (4) of a laundry washing machine while it is in operation with regard to the quality of its placement and the base on which it is placed. The method comprises an active system for detecting the transfer of force to the base, which enables the simultaneous detection of the eccentric and dynamic load in the drum and the identification of the dynamic properties of the washing machine. By controlling the rotational frequency of the washing machine drum, it is possible to actively adjust the washing cycle according to the loads in the drum and the dynamic properties of the washing machine. According to the proposed invention, at least one calibration is anticipated at the user's place of installation of the washing machine, which is used to identify the dynamic properties of the entire washing machine-base system.

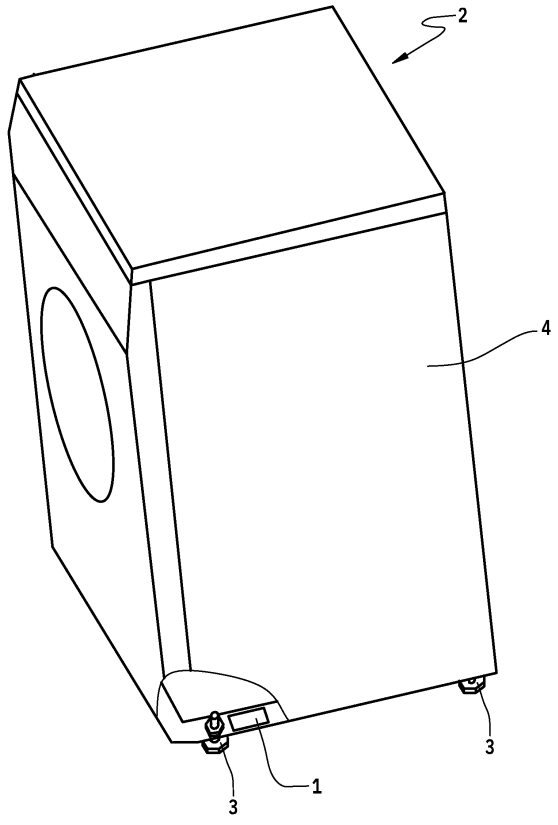

FIG. 1

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Description

[0001] The present invention relates to a method for detecting natural vibration frequencies in a body of a laundry washing machine in operation thereof with regard to the quality of its placement and the base on which it is placed. The washing machine comprises a body with a front wall formed with a loading aperture, a movable door that can be used to close the loading aperture, and a washing tub arranged in said body and comprises an opening facing the front wall of said body and a washing drum for receiving laundry, whereby the washing drum comprises an opening that is at least approximately aligned with the opening of said tub and said loading aperture in the front wall, sensor means for directly or indirectly measuring vibrations, and a memory unit, a processing unit, a control unit, and a display unit.

[0002] During the operation of the washing machine, mainly due to the eccentricity of the centre of gravity of the laundry rotating together with the drum, relatively large centrifugal forces occur that exert dynamic forces on the tub in which the drum is placed and also on the washing machine body via connecting elements such as springs and damping elements. A large part of these forces is transmitted to the surrounding area via the support legs of the washing machine, which are attached to the body of the washing machine. As a result, elements of the surrounding structure may vibrate and unwanted noise may occur. Significant increase in the vibration amplitudes occurs in the resonance operating range of the washing machine, i.e. in the case of an interaction between the rotational frequency of the washing machine drum and the natural frequency of the washing machine. The natural frequency of the washing machine depends on the structure of the washing machine as such and by the elasticity of the base on which the washing machine is placed.

[0003] The eccentric distribution of the laundry or its centre of gravity in the drum causes increased vibrations during the operation of the washing machine, which is usually solved by a repeated redistribution of the laundry until an acceptably small eccentricity is achieved. Such a solution is disclosed in U.S. Pat. No. 6,401,284 B1, for example. Despite an acceptably low mass eccentricity of the distributed laundry, the laundry may still be distributed during the operation of the washing machine when the mass eccentricity of the distributed laundry is acceptably low, but at the same time a large mass deviation load is present. However, to eliminate the increased vibrations, the detection of the mass eccentricity of the distributed laundry is not sufficient, as data on the mass deviation load is also required, which the above known solution does not teach.

[0004] From the publication of Patent Application No. WO 2014/004328, a solution is known for reducing the vibrations of the washing machine by installing a three-axle acceleration sensor on the washing group. Such a solution makes it possible to detect an eccentric and mass deviation load in the drum of the washing machine, thus avoiding increased vibrations and the transfer of force to the base in the operating range of the washing machine when spinning is switched on. This type of solution is directed to reduce the vibrations of the washing group or the excitation force but does not provide information on the dynamic properties of the entire washing machine, such as its natural frequency, resonance, etc.

[0005] Moreover, the publication of Patent Application No. DE 10 2015 106 849 A1, discloses installation a three-axial accelerometer on the body of the washing machine, which enables active control of the vibrations of the entire washing machine. Known solutions for active vibration control of a washing machine are based on the measurement of accelerations on the tub or body, whereby the vibration control is performed using the maximum permissible amplitudes without knowledge or identification of the dynamic properties of the washing machine.

[0006] The object of the present invention is to form a method for detecting the natural frequencies of vibrations in the body of a washing machine during its operation with regard to the quality of its placement and the base on which it is placed.

[0007] According to the present invention, the object as set above is solved with an active system for detecting the transfer of force to the base, which enables the simultaneous detection of the eccentric and dynamic load in the drum and the identification of the dynamic properties of the washing machine. By controlling the rotational frequency of the washing machine drum, it is possible to actively adjust the washing cycle according to the loads in the drum and the dynamic properties of the washing machine. According to the present invention, at least one calibration is anticipated at the user's place of installation of the washing machine, which is used to identify the dynamic properties of the entire washing machine-base system.

[0008] Based on the above measured dynamic properties of the entire system, the washing cycle is adjusted to the individual user in order to avoid the operation of the washing machine in the resonance range. Moreover, based on the measurement of the force on the base, the limit value of the permitted force transmission is defined, which ensures a lower level of vibration and consequently a quieter living environment.

[0009] A method according to the invention, in addition to the automatic adjustment of the washing cycle, also offers the user an interactive insight into the quality of the placement of the washing machine on the base. With the proposed method, it is possible to identify a possible incorrect position or uneven load on the support legs of the washing machine, which is reflected in the unstable position of the washing machine on the base.

[0010] The measurement of the force on the base additionally enables the identification of the mass deviation or dynamic load in the washing machine drum. The above load, which shows zero eccentricity, cannot be detected by measuring the torque of the electric motor, thus it is

provided for according to the present invention an indirect measurement of the mass deviation load by means of a simultaneous measurement of the force transmission to the base and an indirect measurement of the eccentricity by means of the torque of the electric motor. An increased transmission of force to the base indicates an eccentric or deviation load, and the data from the electric motor on the eccentricity enables the distinction between these two loads.

[0011] The invention is further described in detail by way of non-limiting embodiment, and with a reference to the accompanying drawings, where

Fig. 1 shows a washing machine with a sensor arrangement for measuring the transmission of force to the base,

Fig. 2 shows a characteristic curve that gives the absolute amplitude of the force transfer to the base,

Fig. 3 shows a characteristic curve that is the basis for determining the quality of the base on which the washing machine is placed,

Fig. 4 shows a weighted characteristic curve that is the basis for deciphering the natural frequency and the corresponding normalised amplitude,

Fig. 5 shows a weighted characteristic curve that is the basis for determining the critical operating ranges,

Fig. 6 shows an embodiment of inserting load means into a washing machine.

[0012] At least one sensor 1 for indirectly measuring the force from a washing machine 2 to a base is placed near at least one of support legs 3 of the washing machine 2, where the deformations of a body 4 of the washing machine 2 are directly related to the magnitude of the transmitted force. The spatial placement of the sensor 1 is arbitrary, preferably in the lower part of the body, particularly in the area of the bottom or near at least one of the support legs 3. The above sensor 1 is attached directly to the washing machine 2 either in a removable or non-removable manner by means of a force-locking, form-locking, or material joint, for example by gluing, riveting, screwing, etc.

[0013] The placement of the sensor 1 on the body 4 in the immediate vicinity of the support legs 3 also enables the indirect determination of the natural frequencies of the washing machine 2 in addition to force measurements. The value of the maximum force at a given frequency of the drum of the washing machine 2 corresponds to the value of the natural frequency of the washing machine 2. In this case, the washing drum of said washing machine 2 must be placed in the washing tub in such a way that it can rotate around an approximately horizontal axis.

[0014] According to the proposed invention, it is envisaged that at least one calibration is performed on site for each user. Throughout the description, the word user refers to both the end user of the washing machine 2 and an advanced user, such as a service technician of the washing machine 2. Using the calibration, the dynamic properties of the washing machine 2 are determined, including the base on which it is placed. Calibration is based on measuring the deformations on the lower part of the body 4 of the washing machine 2, whereby the deformations near at least one of the support legs 3 are measured. According to the invention, there is also the possibility of an embodiment with which said deformations are measured separately by means of a set of sensors 1 in the immediate vicinity of all support legs 3 of the washing machine 2.

[0015] The measurement of deformations is performed using at least one sensor 1, for example with a polymer strain gauge, which directly generates a response in the form of stress during deformation. Compared to the resistance strain gauge, it requires neither the use of additional electronic power supply components nor the final amplification of the signal from the aforementioned sensor 1. The stress signal from at least one sensor 1 can be directly integrated into the existing electronic components of the washing machine 2. All necessary recalculations are performed with the processing power of the aforementioned existing electronic components.

[0016] The sensor 1 can also be mounted on the body 4 of the washing machine 2 indirectly by means of an additional holder, so that the sensor 1 is placed on an additional holder by an adhesion process, after which the sensor and additional holder assembly is mounted on the body 4 of the washing machine 2 by means of a force-locking, form-locking, or material joint.

[0017] The method according to the invention provides that the calibration for determining the natural frequencies of the washing machine 2 is performed when it is installed for the end user. The quality of the base on which the washing machine 2 is placed is evaluated based on the calibration. It is also possible to detect any incorrect placement of the support legs 3 of the washing machine 2 based on an algorithm. This algorithm refers to characteristic resonance ranges, which primarily occur in the case that the washing machine is mainly in contact with the ground only through three support legs 3.

[0018] With the help of a calibration, the critical operating ranges are evaluated with this algorithm. During the operation of the washing machine 2, the washing mode is actively adjusted to avoid operation in critical ranges. By means of the measurement of deformations and in conjunction with the measurement of the torque on the motor of the washing machine 2, it is possible to detect dynamic loads in the drum of the washing machine 2.

[0019] The calibration of the washing machine 2 is carried out in such a way that transport locks 2a, which are intended to prevent damage to the washing machine 2 during transport, are first removed. After placement in the intended place, the washing machine 2 is connected to the water, drain, and electrical connection.

[0020] When the user switches on the washing machine 2, the processing unit of the washing machine proposes to perform the appliance calibration procedure via the display unit. The display of the proposal appears due to the state of the display unit preset by the washing machine 2 manufacturer. When the user confirms the proposal, the display unit shows the symbol for inserting intended load means 2b into the drum of the washing machine 2 (shown in Fig. 6b by a dashed line). The load means 2b must assume the intended position in relation to the inside of the drum when inserted into the drum or during the calibration programme. This is achieved, for example, in such a way that the load means 2b comprise fastening points which coincide with the receiving means in the drum of the washing machine 2. Alternatively, the load means is of such a shape that, when inserted into the drum or during its rotation at a circumferential speed at which the centrifugal force at the centre of gravity of the load means 2b is greater than the weight force thereof, they assume a precisely defined position inside the drum of the washing machine 2. From an economical point of view, it is particularly advantageous if the load means 2b is an integral part of the transport locks 2a.

[0021] Figure 6 shows an embodiment where the load means 2b are part of the transport locks 2a. After inserting the load means 2b into the drum, the user closes the door of the washing machine 2 and starts the calibration by pressing the start button. Of course, communication between the user and the washing machine 2 is also possible in some other known way, such as by voice communication.

[0022] The rotational speed of the drum of the washing machine 2 is automatically increased from the idle state to the final number of revolutions with constant acceleration during the calibration by means of the calibration programme, which is part of the aforementioned algorithm and which includes the course of the angular speed of the electric motor as a function of time. During the gradual increase in the rotational speed of the drum, the signal from the at least one sensor 1 is read and the equivalent force on the base on which the washing machine 2 is placed is recalculated. Both the signal reading and the recalculation use the existing processing power of the washing machine 2, which is merely programmatically upgraded by the aforementioned algorithm, but this is not the subject of the present invention. The result of the calibration is a characteristic curve 5, which gives the absolute amplitude of the force transfer to the base (Fig. 2).

[0023] Based on said characteristic curve 5, a dedicated algorithm deciphers the natural frequencies 5', 5" of the washing machine 2. The values of the natural frequencies 5', 5" are stored in the settings of the washing machine 2, where they remain as default values until the next calibration. The aforementioned algorithm is switched on by the user, and the usual washing mode or silent mode is available. Here, the user is informed that the final spinning speeds may be different from those set under the washing mode.

[0024] During the washing cycles, the so-called silent calibration of the washing machine 2 takes place so that the deformations of the body 4 of the washing machine 2 are measured and the natural frequencies 5', 5" are identified. The values of natural frequencies 5', 5" relative to the washing cycles are recorded in the memory of the washing machine 2, and depending on any changes in the values of natural frequencies 5', 5", the user is informed that the calibration process must be restarted. The reason for changing the natural frequencies 5', 5" can include loose joints in the components of the washing machine 2, a movement of the washing machine 2, a possible unscrewing of the support legs 3, etc. The condition of the washing machine 2 is monitored during its entire service life with the aforementioned silent calibration.

[0025] The result of the performed calibration procedure are the values of the natural frequencies 5', 5" of the washing machine 2 on a given base. For each type of the washing machine 2, the algorithm for detecting the quality of the base gives at least three reference values of the natural frequencies 5', 5", which are determined by the manufacturer of the washing machine 2 under ideal conditions. These reference values of natural frequencies are as follows:

- natural frequency f_{max} of the washing machine 2 on an ideally rigid base,
- natural frequency f_{min} of the washing machine 2 on extremely soft base, and
- natural frequency f3 of the washing machine 2 when only three support legs 3 are in contact with the base on which the washing machine 2 is placed.

[0026] According to the reference values of these natural frequencies 5', 5", it is possible to determine the quality of the base on which the washing machine 2 is placed (Fig. 3). The natural frequency range between f_{min} and f_{max} is divided into a set of classes, preferably five. Based on the range in which the measured natural frequency 5', 5" of the washing machine 2 is located, it is possible to identify the quality of the base. If the washing machine 2 is inadequately supported, this is detected when the natural frequency 5', 5" of the washing machine 2 is close to the natural frequency f3. In this case, the algorithm warns the user that the washing machine 2 is not placed correctly and that it is necessary to start the calibration procedure again.

[0027] The active adjustment of the washing cycle according to the quality of the base is aimed at a quieter and smoother operation of the washing machine 2. The concept is based on the identified natural frequencies 5', 5" within the calibration procedure. The user deliberately selects the smooth and quiet mode of the washing machine 2 by pressing the appropriate button. By means of the instructions, the user is informed that, due to the modified mode of operation of the washing machine 2, the

rotational speed of the washing drum in the spinning phase may be slightly different from the selected rotational speed within the washing programme.

[0028] The aforementioned algorithm for actively adjusting the washing mode comprises the following steps.

[0029] Based on the completed calibration of the washing machine 2, the weighting of the characteristic curve 5 is performed, preferably dividing the amplitudes by the square of the rotational frequency of the washing drum. From the weighted characteristic curve 6, the natural frequencies 5', 5" and corresponding normalised amplitudes are automatically identified via the aforementioned algorithm (Fig. 4).

[0030] Based on the weighted characteristic curve 6, the critical operating ranges are the washing drum rotational frequencies where the response amplitude reached X_{max} of the maximum amplitude of one of the aforementioned natural frequencies 5', 5" (Fig. 5). The frequency ranges suitable for operation are those frequency ranges where the amplitude is lower than X_{min}.

[0031] The above steps are performed as part of the calibration of the washing machine 2, whereby the critical frequency ranges and the frequency ranges suitable for operation are stored in the memory of the washing machine 2 until the next calibration.

[0032] Only the adjustment of the washing cycle is performed at rotational speeds higher than 400 rpm. The adjustment of the washing cycle is preferably carried out in the spinning phase as follows:

- the desired rotational speed of the spinning is identified,
- in critical frequency ranges, the maximum possible acceleration rate is determined in order to pass critical ranges quickly; in other frequency ranges, the acceleration rate is unchanged,
- in the range of the desired rotational frequency of the spinning, the nearest frequency range suitable for operation is identified, after which the washing machine 2 performs the spinning in this frequency range.

[0033] When the washing machine 2 stops, the washing drum brakes with the greatest possible deceleration.

[0034] The detection of dynamic loads is based on the current detection of deformations from the at least one sensor 1 in conjunction with the identification of the torque of the electric motor. The dynamic load is characterised by the fact that it results in zero eccentricity, so it cannot be detected using the torque of the electric motor. However, by measuring the deformations on the body 4, it is possible to detect an increased level of vibrations that occurs in the presence of such deviation and exceptional loads. Furthermore, it is possible to determine whether it is a normal eccentric load or a deviation load using the torque of the electric motor. If the value of the torque does not change, it is obvious that the eccentricity value is small, which indicates a deviation load.

Claims

1. A method for reducing the vibrations of a washing machine body and/or a base on which said washing machine is placed during the operation thereof, said washing machine being loaded from the front, whereby said washing machine comprises a body with a front wall provided with a loading aperture, a movable door with which said loading aperture can be closed, and a washing tub that is placed in said body and comprises an opening facing the front wall of said body and a washing drum for receiving laundry, whereby the washing drum comprises an opening which is at least approximately aligned with the opening of said tub and said loading aperture in the front wall, sensor means for directly or indirectly measuring vibrations, a memory unit, a processing unit, a control unit, and a display unit, ***characterized in that*** it comprises:

   a) detection of the natural frequencies and corresponding vibration amplitudes of a washing machine in relation to a base on which said washing machine is placed by means of sensor means placed in the lower part of the body of the washing machine,
   b) storing of information about the said natural frequencies and corresponding vibration amplitudes and/or the corresponding directly or indirectly measured forces transmitted from the body to the base in a memory unit,
   c) comparing in a processing unit of values of the above amplitudes or forces with the limit values stored in the memory unit,
   d) adjustment of at least one operating programme and/or a display of information for the user on a display unit about the condition of the washing machine and/or the display of instructions to the user about the necessary corrective measures.

2. The method according to claim 1, ***characterized in that*** the above detection of the natural vibration frequencies of the washing machine with the base comprises the following steps:

   a) installation of a load means in the drum of the washing machine,
   b) implementation of the measurement operation programme,
   c) measurement of the vibrations of the body during the execution of this measurement programme with the above sensor means using at least two different rotational speeds of the drum,
   d) comparison of the measured values with the limit values stored in the memory unit.

3. The method according to claim 1, ***characterized in***

that the display of indirect information of the above measured values on the display unit contains the number of revolutions of the drum at which said values have occurred.

4. The method according to claim 1, ***characterized in that*** the above instruction from step d) for the user comprises checking the suitability of the placement of the above washing machine.

5. The method according to claim 1, ***characterized in that*** the above modification of at least one washing programme includes an increase in the transition speed when accelerating and/or decreasing the speed of the washing machine drum through ranges associated with the above natural frequencies.

6. The method according to claim 2, ***characterized in that*** the above adjustment of at least one washing programme includes the omission of the speed of the washing machine drum in the ranges associated with said natural frequencies.

7. A washing machine that is placed on a base during its operation and is loaded from the front, whereby said washing machine comprises a body with a front wall provided with a loading aperture, a movable door with which said loading aperture can be closed, and a washing tub that is placed in said body and comprises an opening facing the front wall of said body and a washing drum for receiving laundry, whereby the washing drum comprises an opening which is at least approximately aligned with the opening of said tub and said loading aperture in the front wall, sensor means for directly or indirectly measuring vibrations, a storage unit, a processing unit, a control unit, and a display unit, ***characterized in that*** it comprises a reduction of the vibrations of the washing machine body and/or the base on which said washing machine is placed during its operation according to the method under any one of claims 1 to 6.

8. The washing machine according to claim 7, ***characterized in that*** the load means to be installed in the drum of the washing machine according to claim 2 are part of the transport locks.

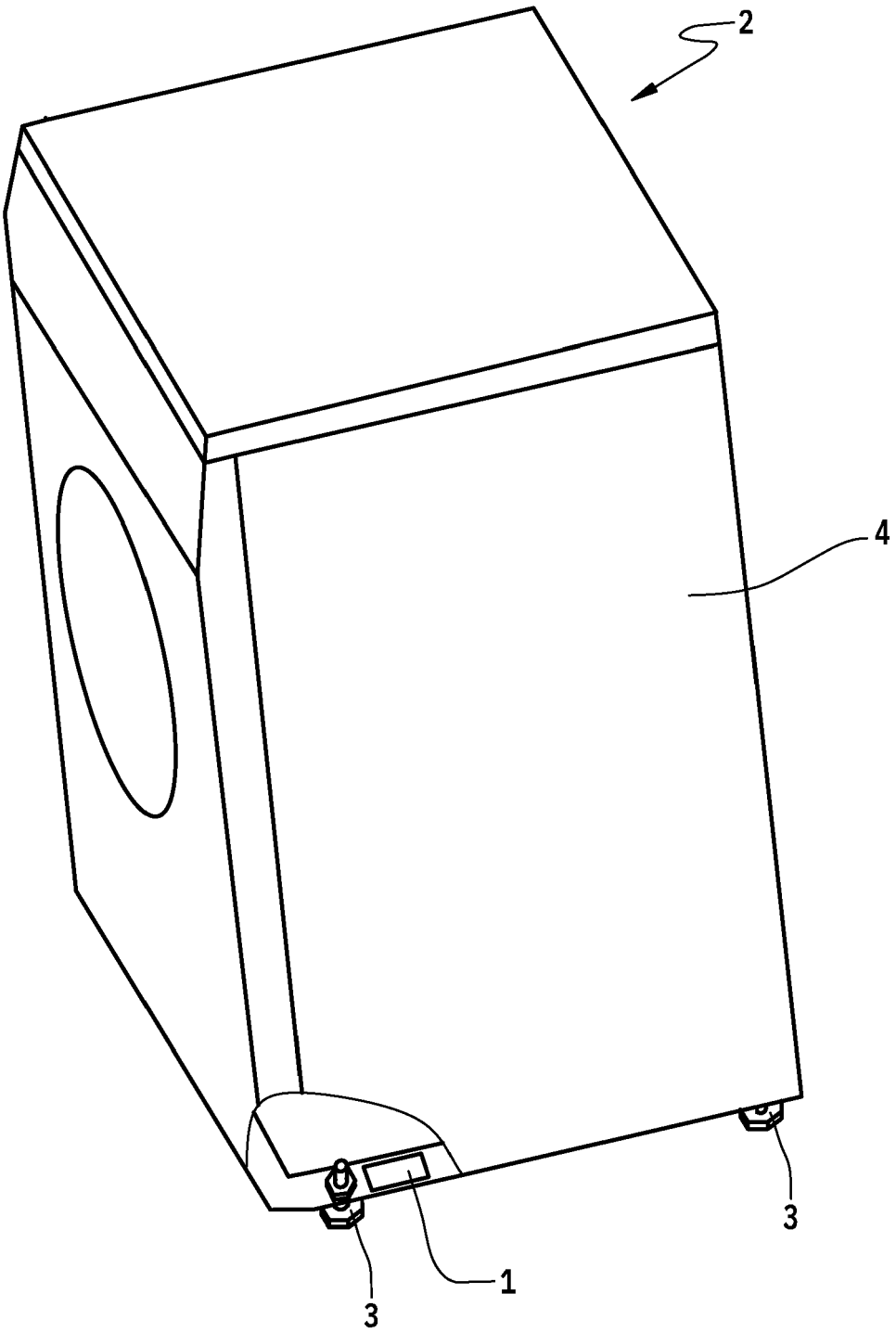

FIG. 1

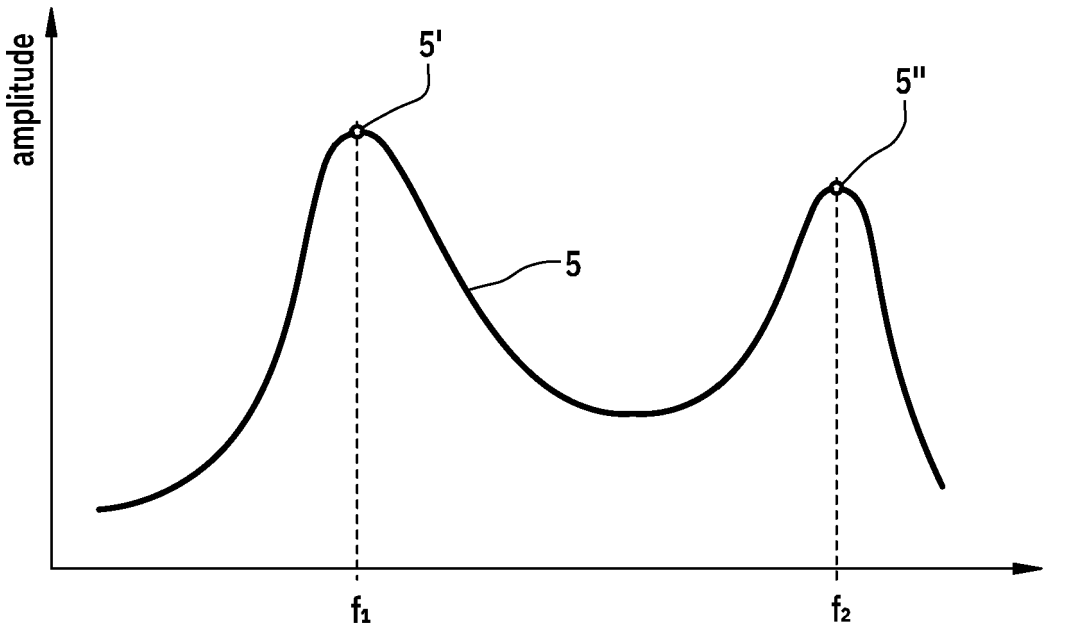
amplitude
5'
5''
5
f1
f2
rotational speed [rpm]

FIG. 2

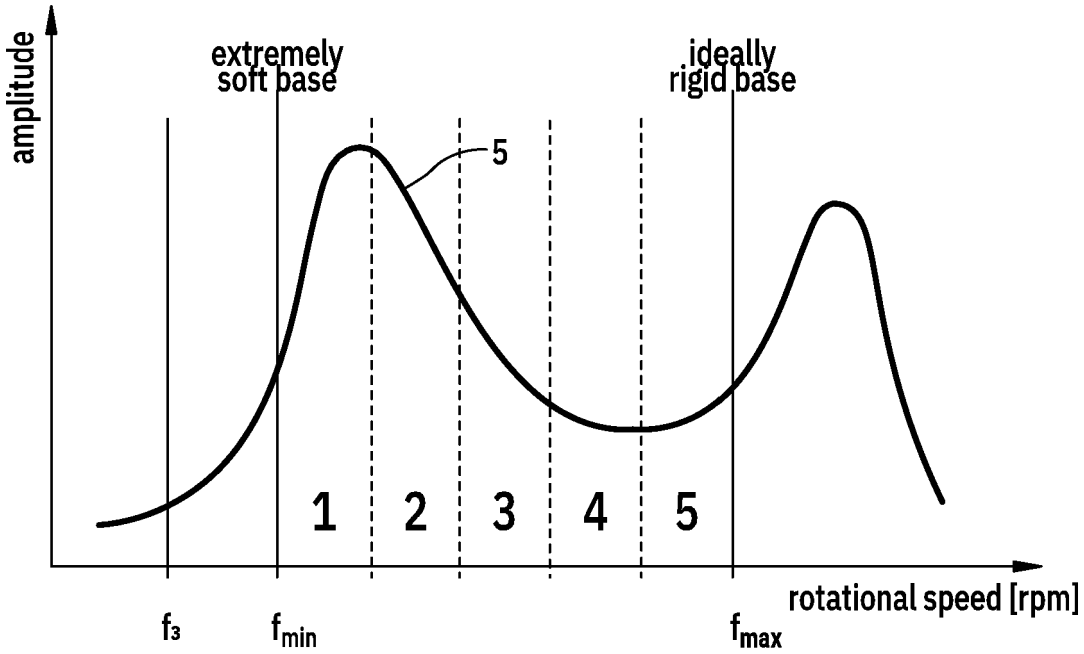
amplitude
extremely soft base
ideally rigid base
5
1
2
3
4
5
f3
fmin
fmax
rotational speed [rpm]

FIG. 3

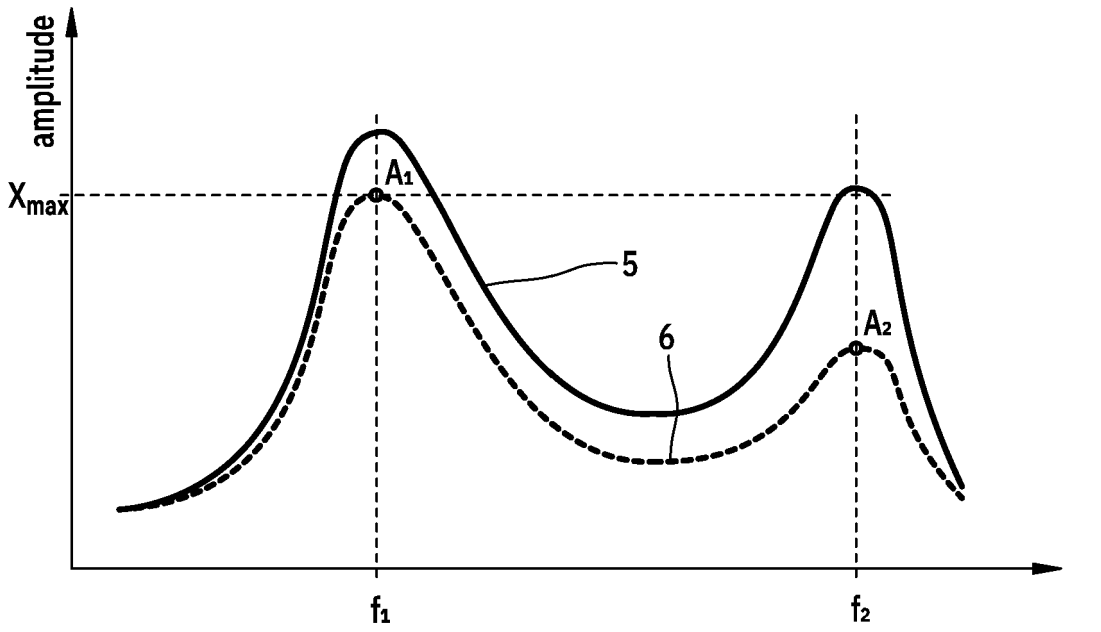
amplitude
X_{max}
A_1
5
6
A_2
f_1
f_2
rotational speed [rpm]

FIG. 4

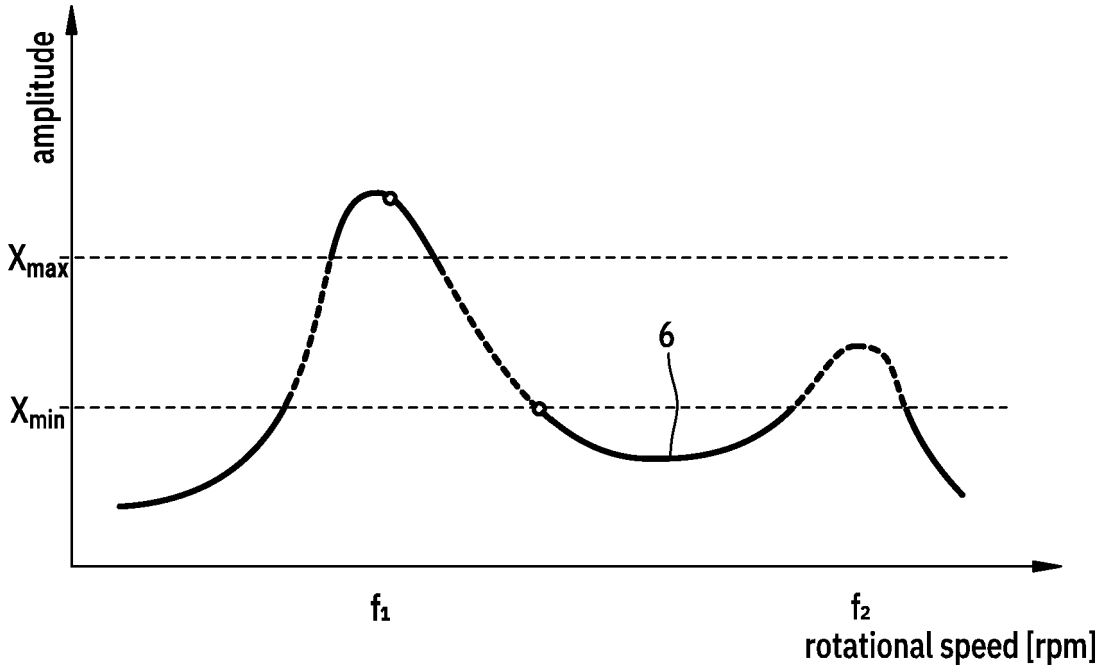
amplitude
X_{max}
X_{min}
6
f_1
f_2
rotational speed [rpm]

FIG. 5

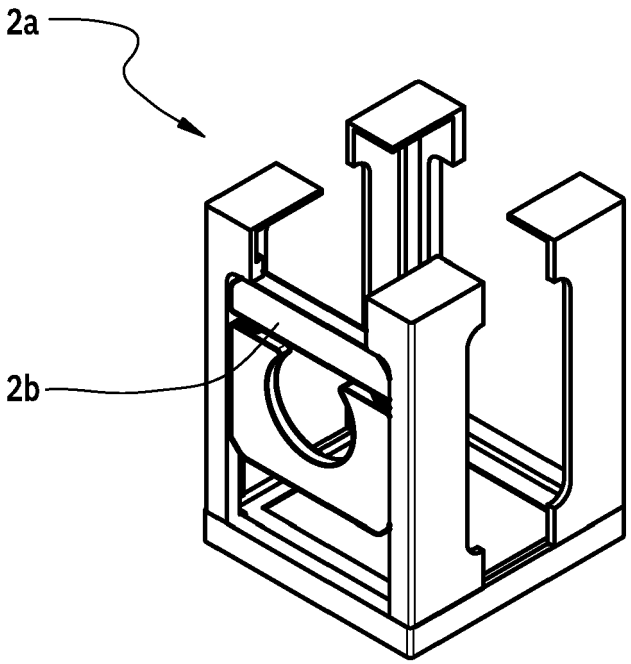

FIG. 6a

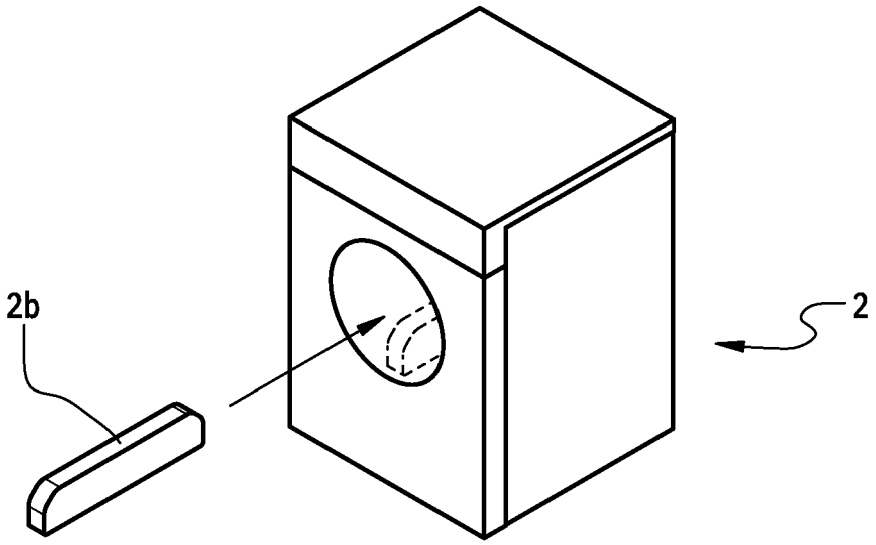

FIG. 6B

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EUROPEAN SEARCH REPORT

Application Number
EP 20 20 6599

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	DE 10 2015 106849 A1 (MIELE & CIE [DE]) 10 November 2016 (2016-11-10) * claims; figures *	1-8	INV. D06F34/16 ADD. D06F105/58 D06F105/52 D06F105/48 D06F103/26
A	US 2017/241064 A1 (BORLIN CHRISTOPHER [US]) 24 August 2017 (2017-08-24) * the whole document *	1-8	
A	US 2015/128357 A1 (KOO KWAN SEO [KR]) 14 May 2015 (2015-05-14) * paragraphs [0027] - [0036]; claims; figure 3 *	1-8	

TECHNICAL FIELDS SEARCHED (IPC)

D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 March 2021	Stroppa, Giovanni

CATEGORY OF CITED DOCUMENTS

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08-03-2021

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