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(54) MEASURING DEVICE FOR DETERMINING THE LOADING AND THE VIBRATIONS OF A WASHER DRUM OF A WASHING MACHINE

(57) This disclosure measuring device for determining the loading and the vibrations of a washer drum (105) of a washing machine. The measuring device (100) comprises two light emitters (102,103) that have different wavelengths and emit light to a reflector (101) having different reflection zones. The reflected light intensity is measured by a light sensor (104), and a displacement of the washer drum (105) is determined based on the measured light intensities for the different wavelengths.

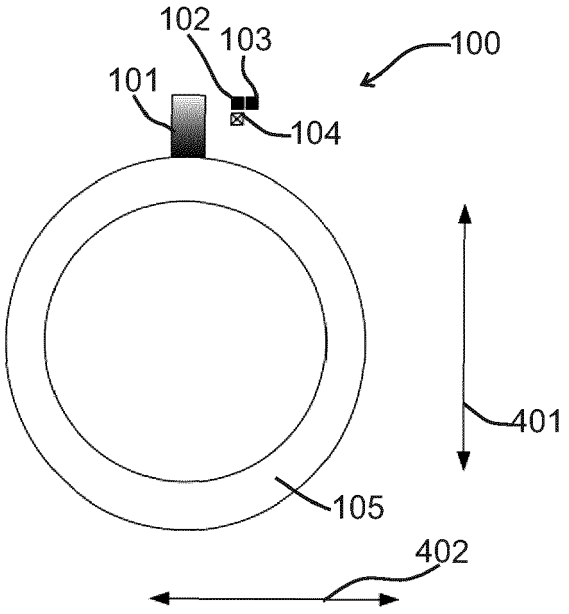

Fig. 4A

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Description

TECHNICAL FIELD

[0001] The present invention relates to determining the loading and/or the level of vibrations of a washer drum of a washing machine. The invention further relates to a measuring device performing such determination, and a washing machine comprising the measuring device. Also, a method for determining the loading and/or the level of vibrations of a washer drum of a washing machine is provided.

TECHNCIAL BACKGROUND

[0002] Generally, a rotating or spinning washer drum of a washing machine is exposed to high stress due to the high rotational speed of the washer drum inside a washing machine body surrounding the washer drum. Therefore, costly bearings are used in order to increase the durability of the washing machine.

[0003] However, when washing the laundry, the stress on a bearing on which the pressure drum is rotatably mounted increases, wherein the increase of stress depends on the weight of the added laundry. The high rotational speeds of the washer drum can cause an accumulation of laundry for example at one side of the washer drum which can lead to noisy vibrations during rotation of the pressure drum. This can further cause increased wear for example of the bearing on which the pressure drum is mounted or could even lead to a collision of the washer drum with the washing machine body surrounding the washer drum. Further, the accumulation of the laundry at one side of the washing drum can lead to the fact that the laundry may not be properly washed, for example if the laundry is wrapped together.

[0004] In order to identify dangerous vibrations or too heavy loading of the washer drum, it is known in the prior art to perform measurements in order to calculate the loading of the pressure drum and the vibrations of the pressure drum during its rotation. However, the state-of-the-art uses different sensors for the measurement of the loading and the measurement of the vibrations, wherein the loading of the washer drum is calculated based on a measured vertical displacement of the drum due to the increased load and an estimation by a software, and the vibrations of the washer drum are measured by an additional excellent accelerometer sensor, wherein the software needs perform at different calculation from the acceleration measurements in order to come to vibration values. Therefore, the necessity of having two different sensors is costly. Further, a more expensive software needs to be used which can perform two different calculation programs.

[0005] Additionally, it is only known to take measurements of a one-dimensional movement of the washer drum, such that only a displacement in one direction can be detected, while a displacement in another direction cannot be detected.

SUMMARY

[0006] Therefore, it is an object of the present invention to overcome the above-mentioned disadvantages of the state of the art, particularly to provide a cost efficient and precise measuring device for determining the loading and the vibrations of a washer drum of a washing machine. Preferably, it shall be possible to measure a two or three dimensional displacement of the washer drum. It is a further object of the present invention to provide a method for determining the loading and the vibrations of the washer drum of a washing machine in accordance with the described measuring device.

[0007] This objective is solved by the subject matter of the independent claims. Advantageous embodiments are subject to the dependent claims and will be set out herein below.

[0008] An example embodiment of the invention provides a measuring device for determining the loading and the vibrations of a washer drum of a washing machine. The use of the measuring device in a washing machine is only exemplary. The measuring device may also be used in different environments or applications, where the rotation of a rotating or spinning part with respect to a stationary part, preferably surrounding the rotating part, is to be monitored and/or controlled.

[0009] The measuring device comprises a first light emitter which is able to emit light of a first wavelength $\lambda 1$ and a second light emitter which is able to emit light of a second wavelength $\lambda 2$. According to a preferred embodiment of the invention, the second wavelength $\lambda 2$ differs from the first wavelength $\lambda 1$. Using different wavelengths allows performing distinct measurements simultaneously. However, it is also possible to use the same wavelength for both light emitters, e.g. when controlling the light emitters in a time-multiplex fashion.

[0010] A reflector is illuminated by the first and the second light emitters in order to at least partially reflect the received light of the first wavelength $\lambda 1$ and of the second wavelength $\lambda 2$. Preferably, the light beam of the first light emitter and the light beam of the second light emitter are focused in a way that the resulting light cones are significantly smaller than the reflector. The first light emitter and the second light emitter can be arranged with respect to the reflector such that the light is illuminated from the light emitters to the reflector in an essentially horizontal manner. The reflector comprises a plurality of reflection zones having different reflection rates (It is apparent that the reflection zones may also be regarded as having different absorption rates). A light receiver measures the intensity of the light being reflected by the reflector, wherein the measured intensity depends on the reflection zone reflecting/absorbing the light beam of the first light emitter and the light beam of the second light emitter, respectively. Thus, the first and the second light emitters illuminate the reflector with light of the wavelength $\lambda 1$ and

wavelength λ2, respectively, and the reflector reflects both the light of the wavelength λ1 and wavelength λ2, respectively, depending on the reflection zone being illuminated by the respective light emitter.

[0011] The measurement arrangement is used to perform measurements by detecting a variation of the measured intensity of the received light between an initial state and a working state which is caused by a first relative displacement of the reflector with regard to the first and second light emitters and the light receiver. The initial state may be defined by an unloaded state of the washer drum, i.e. a state before a washing program that rotates the washer drum is started and in which no laundry is placed in the washing drum. The working state may be defined by a loaded state of the washer drum. This this loaded states the washing drum of the washer performs a rotational movement around its rotational washer drum axis, while laundry is present in the washer drum.

[0012] When the washer drum is loaded with laundry the total mass of the washer drum is increased such that the washer drum is lowered and sinks vertically downwards. This may be achieved by a flexible bearing of the washer drum inside of the washing machine body in order to compensate an increased loading. The addition of laundry into the washer drum may cause a continuous linear vertical displacement of the washer drum leading to an even first relative displacement of the reflector with regard to the first light emitter, the second light emitter and the light receiver relative to the reflector. The reflector or alternatively an assembly formed by the first light emitter, the second light emitter, and the light receiver are fixedly provided on the washer drum.

[0013] Further, a difference between the received light intensity of the wavelength λ1 and the received light intensity of the wavelength λ2 between the initial state and the working state is caused by a different (second) relative displacement of the reflector with regard to the first light emitter and the second light emitter. In case of vibration, which causes the washer drum to perform an unbalanced rotation around its rotational axis, there will be an additional (second) relative displacement of the reflector with regard to the first light emitter, the second light emitter and the light receiver, which can be identified by the measuring device. The second relative displacement is directed off the dimensional axis of the first relative displacement, i.e. the second relative displacement is also at least partially a further dimensional axis. Consequently, the reflector is turned with regard to both light emitters such that the first light emitter (characterized by its first wavelength λ1) illuminates a different reflection zone than the second light emitter (characterized by its second wavelength λ2).

[0014] As a result, a difference between the relative displacement of the first light emitter and the relative displacement of the second light emitter with regard to the reflector can be detected and/or measured. In order to determine and/or calculate the loading of the washer drum based on the first relative displacement and to determine and/or calculate the vibrations of the washer drum based on the second relative displacement, a controller may be foreseen in the measuring device. The controller may be implemented by processing circuitry, e.g. a processor, application specific integrated circuit (ASIC), programmable logic device (PLD), field programmable gate array (FPGA), etc. The processing circuitry may also be provided as part of a System on Chip (SoC).

[0015] In an example embodiment, the positions of the first light emitter, the second light emitter and the light receiver (light sensor) are stationary with regard to each other, so that they form a movement unit. In case of a displacement of the movement unit, the first and second light emitters and the light sensor evenly move relative to the reflector. Particularly, in the initial state the first and the second light emitters each define an initial received light intensity at the light receiver depending on a corresponding initial state reflection zone (for each emitted wavelength). In the working state the first relative displacement involves an equal movement of the first light emitter, the second light emitter and the light sensor. Further, the second relative displacement involves a discrepancy between the relative displacement of the first light emitter and the relative displacement of the second light emitter due to different corresponding working state reflection zones.

[0016] Preferably, the first and the second light emitters are configured as a light-emitting diode (LED), wherein particularly at least one of the wavelength λ1 of the first light emitter and the wavelength λ2 of the second light emitter is in the range of infrared light or visible light. In case of different wavelengths of the first and the second light emitter, the wavelengths λ1 and λ2 are chosen such that they can easily be separated by the light receiver and consequently assigned to the respective light emitter.

[0017] In an embodiment of the invention, the reflector is configured as a preferably rectangular, quadratic or semi-circle shaped, thin strip or plate. The length and/or the width dimension of the strip or plate may be larger than its thickness. The reflector may for example comprise a color or greyscale gradient, particularly from light to dark to define the plurality of reflection zones. The gradient may be a linear gradient, but may also be a circular or elliptic gradient. In generally, the gradient may change in only on direction, but it is also possible to use a gradient which varies in two different directions. The gradient may be continuous, in contrast to having a limited number of defined steps of gradient changes. Apparently, the light absorption of a lighter color will be higher than the absorption of a darker color, which means that the reflection rate of the lighter color is less than the reflection rate of the darker color.

[0018] As indicated above, the plurality of reflection zones may also be curved such that the gradient varies in two directions. The two directions may be perpendicular to each other. The reflector blade lies in the plane defined by gradient directions. In an embodiment, the

reflector is white at the top and black at the bottom (or vice versa). It may be realized by a continuous gradient so that the reflection zones get continuously darker from the top to the bottom.

[0019] In an embodiment, the light receiver/detector/sensor is configured as a photodiode or phototransistor. However also another type of light receivers, e.g. charge coupled devices (CCDs) could be used. The light receiver is designed to detect the light intensities of both, the reflected light having the first wavelength $\lambda 1$ and the reflected light having the second wavelength $\lambda 2$. Hence, only one light receiver needs to be provided for determining the loading as well as the vibrations of the washer drum. Further, the measurement arrangement allows for measuring at least one further dimension of displacement, namely two-dimensional or three-dimensional displacement, of the washer drum with regard to its initial unloaded state. In order to distinguish between the received light from the first light emitter and the second light emitter, the light emitters may use different wavelength. The controller can distinguish between both measured light intensities based on the different wavelengths of the reflected light.

[0020] Another alternative is to perform a chronologically clocked (time-multiplex) illumination of the reflector by the first and second light emitters. This means, that at least temporarily only one of the first and the second light emitters illuminate the reflector such that the reflector temporarily only reflects either light of the wavelength $\lambda 1$ or light of the wavelength $\lambda 2$ such that light receiver receives only input from one of the first and second light emitters at a given point in time. Consequently, the clocking only needs to be adapted to a calculation program of the controller so as to chronologically perform the calculation of the respective relative displacement in a clocked manner with regard to the first light emitter and the second light emitter.

[0021] In an example embodiment, the first light emitter, the second light emitter and the light sensor are vertically or horizontally distributed. In another embodiment, the first light emitter and the second light emitter are horizontally or vertically spaced to each other. The light sensor may be arranged centrally and/or horizontally or vertically spaced with regard to the first and second light emitters. However, the distances between the first light emitter and the second light emitter, the first light emitter and the reflector, the second light emitter and the reflector may be chosen such that emitted light from each of the light emitters is reflected by the reflector and received by the light receiver.

[0022] In a preferred embodiment of the invention, the controller may implement some functional logic (e.g. at least in part by means of a control program) to calculate the loading and vibrations of the washer drum based on the measured light intensities caused by the first and the second relative displacement. The functional logic may compare the calculated loading and/or vibrations with predetermined threshold values of the loading and/or vibrations in order to initiate counteractions. These counteractions may aim to prevent damage and/or wearing of the washer drum and the washing machine. The functional logic may generate control commands to the water supply of the washing machine in order to adjust the amount of water in the washer drum. Alternatively or in addition, the functional logic may generate control commands to a driving means of the washing machine in order to adjust the rotational speed of the washer drum and/or the drive force.

[0023] In an embodiment, calculation of the loading and the vibrations of the washer drum can be performed as follows. Measured initial state light intensities of the wavelengths $\lambda 1$ and $\lambda 2$, respectively, are compared with their corresponding working state light intensities of the wavelengths $\lambda 1$ and $\lambda 2$, respectively.

[0024] The measurement and the comparison can be for example performed periodically. Further, the measurement and the comparison may depend on an angular velocity of the rotating washer drum, i.e. each time the first light emitter, the second light emitter and the light receiver are facing the reflector during rotation of the washer drum a measurement is performed.

[0025] In case of no change in the light intensities for both wavelengths $\lambda 1$ and $\lambda 2$ between the initial state and a rotating state of the washer drum, the measuring device may detect this situation as no laundry being added into the washer drum. In case of equal changes in light intensities for the wavelength $\lambda 1$ and the wavelength $\lambda 2$ between the initial state and the rotating working state of the washer drum, the measuring device recognizes a one-dimensional displacement of the washer drum, which may be interpreted as laundry being present in the washer drum. The extent of the change depends on the weight of the laundry in the washer drum. In case of different changes in light intensity for the wavelength $\lambda 1$ and the wavelength $\lambda 2$ between the initial state and the rotating working state of the washer drum, the measuring device detects a two-dimensional displacement of the washer drum and may interpret as a vibration of the washer drum. The extent of the difference in change in light intensities depends on the strength of the vibrations of the washer drum.

[0026] The measured displacement values may be transformed into magnitudes of the loading and the vibrations of the washer drum using some conversion factor. Counteractions may be triggered by the measuring device based on the magnitudes of the loading and the vibrations of the washer drum. This may involve a comparison of the magnitudes of the loading and the vibrations of the washer drum with predetermined threshold values that define the normal operating state of the washer. If one or more thresholds are exceeded, this may indicate a loading and/or vibration that could cause damage to the washer drum and/or the washing machine and the measuring device may take counteractions. However, it may be advantageous when the counteractions are not performed each time a threshold value is exceeded.

Instead, in one example implementation, the measuring device may determine a running average value from a given number of last measurements/calculations. For example, counteractions may be triggered, if an average value of at least 5, particularly 10, 20, 30 or 50, calculated values exceeds the threshold value. Alternatively, counteractions may be triggered, if a counter exceeds a threshold value, where the counter is incremented when the current measurement of magnitudes of the loading and the vibrations of the washer drum exceeds one or both threshold values for the loading and vibrations, and is decremented otherwise.

[0027] Another embodiment of the invention provides a washing machine with a measuring device according to one of the various embodiments described herein. The washing machine comprises a washer drum being able to rotate around its rotational washer drum axis within a washing machine body surrounding the washer drum. The reflector of the measuring device is fixedly mounted to a periphery of the washer drum and the first light emitter, the second light emitter and the light receiver are fixedly mounted on an inner surface of the washing machine body and at least temporarily face the reflector during rotation of the washer drum, or vice versa. Preferably, the washer drum comprises a cylindrical shape and the washing machine body comprises a substantially cuboid shape, wherein particularly the cylinder end faces are parallel to a corresponding inner surface of the washing machine body. In a preferred embodiment, the reflector is mounted on one of the end faces of the cylindrical washer drum, preferably a back side of the pressure drum, and the first and the second light emitters as well as the light receiver are mounted on an inner surface of the washing machine body facing the pressure drum end face at least temporarily during relative rotation of the pressure drum with respect to the washing machine body.

[0028] Further, embodiments provide a method of using a measuring device for determining the loading and the vibrations of a washer drum of a washing machine.

[0029] It is noted that a method can be defined such that it realizes the measuring of the loading and the vibrations of a washer drum of the washing machine according to the described aspects of the invention, and vice versa.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, functionality, etc. in order to provide a thorough understanding of the various aspects of the claimed invention.

[0031] However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the invention claimed may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

Fig. 1A shows a schematic sideview of a washer drum comprising a measuring device according to an exemplary embodiment of the invention, wherein a reflector of the measuring device is not provided on the washer drum;

Fig. 1B shows a schematic sideview of the washer drum of Fig. 1A comprising a measuring device according to an exemplary embodiment of the invention, wherein the reflector of the measuring device is provided on the washer drum;

Fig. 2A shows a reflector according to the measuring device according to an exemplary embodiment of the invention having a greyscale gradient with a lighter color at the top and a darker color at the bottom;

Fig. 2B shows a reflector according to the measuring device according to an exemplary embodiment of the invention having a greyscale gradient with a darker color at the top and a lighter color at the bottom;

Fig. 2C shows a reflector according to the measuring device according to an exemplary embodiment of the invention having a greyscale gradient having curved reflection zones, wherein a lighter color is provided at top and a darker color is provided at the bottom;

Fig. 2D shows a reflector according to the measuring device according to an exemplary embodiment of the invention having a greyscale gradient having curved reflection zones, wherein a darker color is provided at top and a lighter color is provided at the bottom;

Fig. 3A shows a schematic exemplary arrangement of a first light emitter, a second light emitter and a light receiver according to an exemplary embodiment of the invention;

Fig. 3B shows an alternative schematic exemplary arrangement of the first light emitter, the second light emitter and the light receiver according to an exemplary embodiment of the invention;

Fig. 4A shows a schematic arrangement of a meas-

uring device according to an exemplary embodiment of the invention on a washer drum of the washing machine;

Fig. 4B shows exemplary relative arrangements of the reflector with regard to the first light emitter, the second light emitter and the light receiver of a measuring device according to an exemplary embodiment of the invention;

Fig. 5 shows a schematic view of the measuring device according to the an embodiment of an exemplary embodiment of the invention;

Fig. 6 shows an exemplary method of using the measuring device according to an exemplary embodiment of the invention; and

Fig. 7 shows the method of using the measuring device according to Fig 6 with an exemplary method of introducing counteractions.

DETAILED DESCRIPTION

[0032] In the following detailed description of preferred embodiments of the present invention a measuring device for determining the loading and the vibrations of a washer drum 105 of a washing machine (not shown) is generally indicated by the reference number 100.

[0033] In Fig. 5, an exemplary measuring device 100 is schematically illustrated. The measuring device 100 comprises a first light-emitting diode 102 which is able to emit light of a first wavelength $\lambda 1$, a second light-emitting diode 103 which is able to emit light of a second wavelength $\lambda 2$, a greyscale gradient reflector plate 101 and a light receiving photodiode 104. Using different wavelengths allows performing distinct measurements simultaneously. However, it is also possible to use the same wavelength for both light emitters, e.g. when controlling the light emitters in a time-multiplex fashion.

[0034] Referring to Fig. 1A, a schematic sideview of the washer drum 105 of the washing machine is shown. The washer drum 105 is arranged such that a cylinder end face 107 is oriented in parallel to an inner surface 109 of the washing machine. The measuring device 100 is provided such that the first light-emitting diode (LED) 102, the second light-emitting diode (LED) 103 and the light receiving photodiode 104 are fixedly mounted to the cylinder end face 107 and the greyscale gradient reflector plate 101 is fixedly mounted to the inner washing machine surface 109. As illustrated, the first LED 102, the second LED 103 and the light receiving photodiode 104 are arranged to at least temporarily face the greyscale gradient reflector plate 101 during a rotational movement of the washer drum 105 in order to perform the measuring process, namely to enable the first and the second LEDs 102, 103 to illuminate the greyscale gradient reflector plate 101, which then reflects the received light of the first and the second LEDs 102, 103 to the light receiving photodiode 104.

[0035] It can be seen, that the vertical dimension of the greyscale gradient reflector plate 101 is bigger than the vertical dimensions of each of the first and second LEDs 102, 103 and the light receiving photodiode 104, which ensures that at least part of the light from the light emitters 102, 103 is reflected by the greyscale gradient reflector plate 101 in order to reach the light receiving photodiode 104 to have input data for the calculation process for determining the loading and the vibrations of the washer drum 105. The light irradiated from the first and second LEDs 102, 103 is shown by arrows indicated by the reference number 111, wherein the reflected light from the greyscale gradient reflector plate 101 is indicated by a dotted arrow having the reference number 113. During rotation, the greyscale gradient reflector plate 101 is stationarily mounted on the inner washing machine surface 109 wherein the first LED 102, the second LED 103 and the light receiving photodiode 104 are rotated according to the rotational speed of the washer drum 105. Therefore, when the greyscale gradient reflector plate 101 faces the light emitters 102, 103 and the light receiving photodiode 104 during their rotational movement, temporarily light is reflected by the greyscale gradient reflector plate 101 and identified by the light receiving photodiode 104 to perform the calculation process, namely to calculate the loading of the washer drum and the vibrations of the washer drum 105.

[0036] According to Fig. 1B, an alternative embodiment of the measuring device is shown which differentiates from the embodiment according to Fig. 1A in that the greyscale gradient reflector plate 101 is fixedly mounted on the cylinder end face 107 of the washer drum 105 and the first LED 102, the second LED 103, and the light receiving photodiode 104 are stationarily fixedly mounted on the inner washing machine surface 109. The light emission, reflection and reception as well as the calculation process are performed analogously to above-described embodiment.

[0037] The greyscale gradient reflector plate 101 is illuminated by the first and the second LED 102, 103 in order to at least partially reflect the received light of the first wavelength $\lambda 1$ and of the second wavelength $\lambda 2$. Preferably, the light beam of the first LED 102 and the light beam of the second LED 103 are focused in a way that the resulting light cones are significantly smaller than the greyscale gradient reflector plate 101. The first LED 102 and the second LED 103 can be arranged with respect to the greyscale gradient reflector plate 101 such that the light is illuminated from the LEDs to the greyscale gradient reflector plate 101 in an essentially horizontal manner. The greyscale gradient reflector plate 101 comprises a plurality of reflection zones 201having different reflection rates (It is apparent that the reflection zones 201may also be regarded as having different absorption rates). A light receiving photodiode 104 measures the intensity of the light being reflected by the greyscale gra-

dient reflector plate 101, wherein the measured intensity depends on the reflection zone 201reflecting/absorbing the light beam of the first LED 102 and the light beam of the second LED 103, respectively. Thus, the first and the second LED 102, 103 illuminate the greyscale gradient reflector plate 101 with light of the wavelength λ1 and wavelength λ2, respectively, and the greyscale gradient reflector plate 101 reflects both the light of the wavelength λ1 and wavelength λ2, respectively, depending on the reflection zone 201being illuminated by the respective LED.

[0038] In an embodiment of the invention, the greyscale gradient reflector plate 101 is configured as a rectangular plate. The length and/or the width dimension of the strip or plate may be larger than its thickness. The greyscale gradient reflector plate 101 may for example comprise a color or greyscale gradient, particularly from light to dark to define the plurality of reflection zones. The gradient may be a linear gradient, but may also be a circular or elliptic gradient. In generally, the gradient may change in only on direction, but it is also possible to use a gradient which varies in two different directions. The gradient may be continuous, in contrast to having a limited number of defined steps of gradient changes. Apparently, the light absorption of a lighter color will be higher than the absorption of a darker color, which means that the reflection rate of the lighter color is less than the reflection rate of the darker color.

[0039] Fig. 2A to 2D show different embodiments of an exemplary greyscale gradient reflector plate 101, wherein the greyscale gradient reflector plate 101 according to Fig. 2A and 2B comprises straight reflection zones 201A, 201B and the greyscale gradient reflector plate 101 according to Fig. 2C and 2D the reflection zones 201C, 201D. The preferably rectangular shaped greyscale gradient reflector plate 101, having a length and/or with dimension being larger than its thickness, comprises a color gradation in the manner of a greyscale from light to dark (Figs. 2A, 2C), respectively from dark to light (Figs. 2B, 2D). The plurality of reflection zones 201A to 201D are defined by the gradient such that the intensity of reflected light from the greyscale gradient reflector plate 101 depends on the position of the reflection zone 201A to 201D along the extension of the greyscale gradient reflector plate 101. To summarize, the lighter the reflection zone 201is, the higher is the intensity of reflected light received by the light receiving photodiode 104 which is transformed into information on the washer drum 105 loading and the washer drum 105 vibrations.

[0040] The reflection zones 201C, 201D according to Fig. 2C and 2D are curved, particularly in order to determine and/or measure a preferably two-dimensional displacement of the washer drum 105 with respect to its initial, preferably unloaded, state. For example regarding the greyscale gradient reflector plate 101C in Fig 2C, the reflection zones 201 C vary in two directions, namely vary from the top to the bottom and from the right to the left such that a two-dimensional displacement of the washer drum 105 can be measured.

[0041] The exemplary measurement arrangement, particularly according to Fig. 4A, is used to perform measurements by detecting a variation of the measured intensity of the received light between an initial state and a working state which is caused by a first relative displacement of the greyscale gradient reflector plate 101 with regard to the first and second LED 102, 103 and the light receiving photodiode 104. The initial state may be defined by an unloaded state of the washer drum 105, i.e. a state before a washing program that rotates the washer drum 105 is started and in which no laundry is placed in the washing drum. The working state may be defined by a loaded state of the washer drum 105. This this loaded states the washing drum of the washer performs a rotational movement around its rotational washer drum 105 axis, while laundry is present in the washer drum 105.

[0042] When the washer drum 105 is loaded with laundry the total mass of the washer drum 105 is increased such that the washer drum 105 is lowered and sinks vertically downwards. This may be achieved by a flexible bearing of the washer drum 105 inside of the washing machine body in order to compensate an increased loading. The addition of laundry into the washer drum 105 may cause a continuous linear vertical displacement of the washer drum 105 leading to an even first relative displacement of the greyscale gradient reflector plate 101 with regard to the first LED 102, the second LED 103 and the light receiving photodiode 104 relative to the greyscale gradient reflector plate 101. The greyscale gradient reflector plate 101 or alternatively an assembly formed by the first LED 102, the second LED 103, and the light receiving photodiode 104 are fixedly provided on the washer drum 105.

[0043] Further, a difference between the received light intensity of the wavelength λ1 and the received light intensity of the wavelength λ2 between the initial state and the working state is caused by a different (second) relative displacement of the greyscale gradient reflector plate 101 with regard to the first LED 102 and the second LED 103. In case of vibration, which causes the washer drum 105 to perform an unbalanced rotation around its rotational axis, there will be an additional (second) relative displacement of the greyscale gradient reflector plate 101 with regard to the first LED 102, the second LED 103 and the light receiving photodiode 104, which can be identified by the measuring device 100. The second relative displacement is directed off the dimensional axis of the first relative displacement, i.e. the second relative displacement is also at least partially a further dimensional axis. Consequently, the greyscale gradient reflector plate 101 is turned with regard to both LEDs such that the first LED 102 (characterized by its first wavelength λ1) illuminates a different reflection zone 201than the second LED 103 (characterized by its second wavelength λ2).

[0044] As a result, a difference between the relative displacement of the first LED 102 and the relative displacement of the second LED 103 with regard to the grey-

scale gradient reflector plate 101 can be detected and/or measured. In order to determine and/or calculate the loading of the washer drum 105 based on the first relative displacement and to determine and/or calculate the vibrations of the washer drum 105 based on the second relative displacement, a controller (not shown) may be foreseen in the measuring device 100. The controller may be implemented by processing circuitry, e.g. a processor, application specific integrated circuit (ASIC), programmable logic device (PLD), field programmable gate array (FPGA), etc. The processing circuitry may also be provided as part of a System on Chip (SoC).

[0045] In an example embodiment, the positions of the first LED 102, the second LED 103 and the light receiving photodiode 104 are stationary with regard to each other, so that they form a movement unit. In case of a displacement of the movement unit, the first and second LED 102, 103 and the light sensor evenly move relative to the greyscale gradient reflector plate 101. Particularly, in the initial state the first and the second LED 102, 103 each define an initial received light intensity at the light receiving photodiode 104 depending on a corresponding initial state reflection zone 201(for each emitted wavelength). In the working state the first relative displacement involves an equal movement of the first LED 102, the second LED 103 and the light sensor. Further, the second relative displacement involves a discrepancy between the relative displacement of the first LED 102 and the relative displacement of the second LED 103 due to different corresponding working state reflection zones.

[0046] However, the plurality of reflection zones 201may also be curved such that the gradient varies in two directions. The two directions may be perpendicular to each other. The greyscale gradient reflector plate 101 blade lies in the plane defined by gradient directions. In an embodiment, the greyscale gradient reflector plate 101 is white at the top and black at the bottom (or vice versa). It may be realized by a continuous gradient so that the reflection zones 201get continuously darker from the top to the bottom.

[0047] In an embodiment, the light receiver/detector/sensor is configured as a photodiode or phototransistor. However also another type of light receiving photodiode 104s, e.g. charge coupled devices (CCDs) could be used. The light receiving photodiode 104 is designed to detect the light intensities of both, the reflected light having the first wavelength $\lambda 1$ and the reflected light having the second wavelength $\lambda 2$. Hence, only one light receiving photodiode 104 needs to be provided for determining the loading as well as the vibrations of the washer drum 105. Further, the measurement arrangement allows for measuring at least one further dimension of displacement, namely two-dimensional or three-dimensional displacement, of the washer drum 105 with regard to its initial unloaded state. In order to distinguish between the received light from the first LED 102 and the second LED 103, the LEDs may use different wavelength. The controller can distinguish between both measured light intensities based on the different wavelengths of the reflected light.

[0048] Another alternative is to perform a chronologically clocked (time-multiplex) illumination of the greyscale gradient reflector plate 101 by the first and second LED 102, 103. This means, that at least temporarily only one of the first and the second LED 102, 103 illuminate the greyscale gradient reflector plate 101 such that the greyscale gradient reflector plate 101 temporarily only reflects either light of the wavelength $\lambda 1$ or light of the wavelength $\lambda 2$ such that light receiving photodiode 104 receives only input from one of the first and second LED 102, 103 at a given point in time. Consequently, the clocking only needs to be adapted to a calculation program of the controller so as to chronologically perform the calculation of the respective relative displacement in a clocked manner with regard to the first LED 102 and the second LED 103.

[0049] In an example embodiment, the first LED 102, the second LED 103 and the light sensor are vertically or horizontally distributed. In another embodiment, the first LED 102 and the second LED 103 are horizontally or vertically spaced to each other. The light sensor may be arranged centrally and/or horizontally or vertically spaced with regard to the first and second LED 102, 103. However, the distances between the first LED 102 and the second LED 103, the first LED 102 and the greyscale gradient reflector plate 101, the second LED 103 and the greyscale gradient reflector plate 101 may be chosen such that emitted light from each of the LEDs is reflected by the greyscale gradient reflector plate 101 and received by the light receiving photodiode 104.

[0050] In Fig. 3A and 3B, two schematic exemplary arrangements of the first LED 102, the second LED 103 and the light receiving photodiode 104 are shown. According to Fig. 3A, the first LED 102A and the second LED 103A are horizontally spaced to each other, wherein the light receiving photodiode 104A is arranged centrally and vertically downwardly spaced with regard to the first and the second LEDs 102A, 103A. According to Fig. 3B, the first LED 102B, the second LED 103B and the light receiving photodiode 104B are evenly vertically distributed with respect to each other, wherein the light receiving photodiode 104B is arranged at a lowermost position of the first and second LEDs 102B, 103B and the light receiving photodiode 104B.

[0051] In a preferred embodiment of the invention, the controller may implement some functional logic (e.g. at least in part by means of a control program) to calculate the loading and vibrations of the washer drum 105 based on the measured light intensities caused by the first and the second relative displacement. The functional logic may compare the calculated loading and/or vibrations with predetermined threshold values of the loading and/or vibrations in order to initiate counteractions. These counteractions may aim to prevent damage and/or wearing of the washer drum 105 and the washing machine. The functional logic may generate control com-

mands to the water supply of the washing machine in order to adjust the amount of water in the washer drum 105. Alternatively or in addition, the functional logic may generate control commands to a driving means of the washing machine in order to adjust the rotational speed of the washer drum 105 and/or the drive force.

[0052] In an embodiment, calculation of the loading and the vibrations of the washer drum 105 can be performed as follows. Reference is also made to the exemplary flow charts in Fig. 6, 7 according to exemplary methods of using the measuring device. Similar method steps between Fig. 6, 7 are increased by 100.

[0053] The measurement and the comparison can be for example performed periodically. Further, the measurement and the comparison may depend on an angular velocity of the rotating washer drum 105, i.e. each time the first LED 102, the second LED 103 and the light receiving photodiode 104 are facing the greyscale gradient reflector plate 101 during rotation of the washer drum 105 a measurement is performed (steps 601 to 605 and 701 to 705).

[0054] In case of no change in the light intensities for both wavelengths $\lambda 1$ and $\lambda 2$ between the initial state and a rotating state of the washer drum 105, the measuring device 100 may detect this situation as no laundry being added into the washer drum 105. In case of equal changes in light intensities for the wavelength $\lambda 1$ and the wavelength $\lambda 2$ between the initial state and the rotating working state of the washer drum 105, the measuring device 100 recognizes a one-dimensional displacement of the washer drum 105, which may be interpreted as laundry being present in the washer drum 105. The extent of the change depends on the weight of the laundry in the washer drum 105. In case of different changes in light intensity for the wavelength $\lambda 1$ and the wavelength $\lambda 2$ between the initial state and the rotating working state of the washer drum 105, the measuring device 100 detects a two-dimensional displacement of the washer drum 105 and may interpret as a vibration of the washer drum 105. The extent of the difference in change in light intensities depends on the strength of the vibrations of the washer drum 105.

[0055] The measured displacement values may be transformed into magnitudes of the loading and the vibrations of the washer drum 105 using some conversion factor (step 606 and 706). Counteractions may be triggered by the measuring device 100 based on the magnitudes of the loading and the vibrations of the washer drum 105. This may involve a comparison of the magnitudes of the loading and the vibrations of the washer drum 105 with predetermined threshold values that define the normal operating state of the washer. If one or more thresholds are exceeded, this may indicate a loading and/or vibration that could cause damage to the washer drum 105 and/or the washing machine and the measuring device 100 may take counteractions. However, it may be advantageous when the counteractions are not performed each time a threshold value is exceeded. Instead, in one example implementation, the measuring device 100 may determine a running average value from a given number of last measurements/calculations. For example, counteractions may be triggered, if an average value of at least 5, particularly 10, 20, 30 or 50, calculated values exceeds the threshold value.

[0056] An alternative method is exemplarily illustrated in Fig. 7 where counteractions may be triggered if a counter exceeds a threshold value. The counter is incremented when the current measurement of magnitudes of the loading and the vibrations of the washer drum 105 exceeds one or both threshold values for the loading and vibrations, and is decremented otherwise (steps 707, 708a, b). If the counter then exceeds a predetermined counter threshold value a counteraction is triggered (steps 709, 710).

[0057] Referring to Fig. 4A, a schematic view of a front side of the washer drum 105 is shown, wherein the greyscale gradient reflector plate 101 is mounted on a periphery of the washer drum 105. The first LED 102, the second LED 103 and the light receiving photodiode 104 are spaced apart from the greyscale gradient reflector plate 101. A vertical direction, corresponding to a vertical displacement of the washer drum 105, is indicated by an arrow 401, a horizontal direction, corresponding to a horizontal displacement of the washer drum 105, is indicated by an arrow 402.

[0058] Based on the arrangement of the components and on the definition of the horizontal respectively to vertical direction, Fig. 4B illustrates exemplary relative positions respectively displacements of the greyscale gradient reflector plate 101 with respect to the first and second LEDs 102, 103 and light receiving photodiode 104, each corresponding to a point of time, at which light is emitted by the light emitters 102, 103 to the greyscale gradient reflector plate 101, and then reflected by the greyscale gradient reflector plate 101 in direction to the light receiving photodiode 104 as input data for calculating the loading and/or the vibrations of the washer drum 105 by the processor (not shown). Position 403 indicates an initial state of the washer drum 105, respectively an initial arrangement of the greyscale gradient reflector plate 101 with respect to the first LED 102, the second LED 103 and the light receiving photodiode 104. As can be seen, a reference line 407 defines a lowermost position of the greyscale gradient reflector plate 101 in the initial state of the washer drum 105. Positions 404a, 404b illustrate a change of the loading of the washer drum 105 which leads to a vertical displacement of the greyscale gradient reflector plate 101 being mounted on the washer drum 105.consequently, in comparison to position 403, the first LED 102 and the second LED 103 now eliminate different reflection zones 201 such that the light receiving photodiode 104 receives different light intensity values for light having the wavelength $\lambda 1$ and also for light having the wavelength $\lambda 2$ reflected from the greyscale gradient reflector plate 101, in comparison to position 403. Therefore, a difference of the light intensity of the wavelength

λ1 between position 403 and positions 404a, 404b equals a difference of the light intensity of the wavelength λ2 between position 403 and positions 404a, 404b.

[0059] Referring now to positions 405a, 405b, the greyscale gradient reflector plate 101 has performed a further relative displacement with regard to the light emitters 102, 103 and the light receiving photodiode 104, namely a turning displacement, preferably in combination with a horizontal displacement, which is caused by an unbalance due to an accumulation of laundry within the washer drum 105. The first LED 102 and the second LED 103 are facing and therefore illuminating different reflection zones 201, thereby causing different reflection intensities which lead to different light intensities received by the light receiving photodiode 104. As a consequence, a difference of the light intensity of the wavelength λ1 between position 403 and positions 405a, 404b does not equal a difference of the light intensity of the wavelength λ2 between position 403 and positions 404a, 404b. The differences can now be compared by the processor (not shown) with predetermined particularly threshold values indicating a critical vibration value of the washer drum 105 in order to monitor an operation of the washer drum 105 and/or to control the operation of the washer drum 105 by performing counter actions, respectively adjust a water supply or a driving force, in order to prevent the washer drum 105, and therefore the washing machine, from damage and/or increased wear and noise. Below table illustrates the measurement of the light receiving photodiode 104.

[0060] Generally, the reflected light emitted by the light emitters 102, 103 is measured by the light receiving photodiode 104, after being reflected by the greyscale gradient reflector plate 101. The received light intensity is separated and respectively assigned to the corresponding one of the light emitters 102, 103 by the processor (not shown) based on the known different wavelengths λ1 and λ2 of the light emitters or due to a chronological clocking of the illumination of the greyscale gradient reflector plate 101 by the light emitters 102, 103. Then the received light intensities associated to the respective light emitters 102, 103 may be quantized so as to have values in a predetermined range, e.g. between o and 10. The measured value (M1) for the first LED 102 and the measured value (M2) for the second LED 102 for each position 403 to 405b according to an example maybe as follows:

Position 403	M1=3/10	and	M2=3/10;
Position 404a	M1=4/10	and	M2=4/10;
Position 404b	M1=2/10	and	M2=2/10;
Position 405a	M1=3/10	and	M2=2/10; and
Position 405b	M1=4/10	and	M3=2/10.

[0061] For the positions 403 to 404b, the measurements, respectively the light intensity values, generated for the first LED 102 and the second LED 103 equal each other, wherein for the positions 405a, 405b the measured light intensity values for the first LED 102 differ from the measured light intensity values for the second LED 103.

[0062] The features disclosed in the above description, the figures and the claims may be significant for the realization of the invention in its different embodiments individually as in any combination.

Reference Sign List

[0063]

100	measuring device
101	reflector
102	first light emitter
103	second light emitter
104	light receiver
105	washer drum
107	cylinder end face
109	in a surface
111	light emission from the light emitters
113	light reflection from the reflector
201A - 201D	reflection zones
401	vertical direction
402	horizontal direction
407	reference line
M1	measured value for the first light emitter
M2	measured value for the second light emitter

Claims

1. Measuring device for determining the loading and the vibrations of a washer drum of a washing machine, comprising:

   a first light emitter emitting light of a first wavelength λ1;
   a second light emitter emitting light of a second wavelength λ2, wherein particularly the second wavelength λ2 differs from the first wavelength λ1;
   a reflector being illuminated by the first and the second light emitters and at least partially reflecting the light having the first wavelength λ1 and the light having the second wavelength λ2, the reflector comprising a plurality of reflection zones having different reflection rates;
   a light receiver for measuring the intensity of the light being reflected by the reflector, wherein the measured intensity depends on the reflection zone, such that a variation of the measured intensity of the received light between an initial state, particularly unloaded state of the washer drum, and a working state, particularly loaded state of the washer drum, is caused by a first relative displacement of the reflector with regard to the first and second light emitters and the light

receiver, and that a difference between the received light intensity of the wavelength λ1 and the received light intensity of the wavelength λ2 between the initial and the working state is caused by a different second relative displacement of the reflector with regard to the first light emitter and the second light emitter; and
a processor for determining the loading of the washer drum based on the first relative displacement and for determining the vibrations of the washer drum based on the second relative displacement.

2. Measuring device according to claim 1, wherein the positions of the first light emitter, the second light emitter and the reflector are stationary with regard to each other, preferably to form a movement unit, wherein particularly in the initial state the first and the second light emitters each define an initial received light intensity at the light receiver depending on a corresponding initial state reflection zone, wherein in the working state the first relative displacement involves an equal movement of the first light emitter, the second light emitter and the reflector, and the second relative displacement involves a discrepancy between the relative displacement of the first light emitter and the relative displacement of the second light emitter due to different corresponding working state reflection zones.

3. Measuring device according to any of the preceding claims, wherein the first and the second light emitters are configured as a light-emitting diode, wherein particularly at least one of the wavelengths λ1 of the first light emitter and λ2 of the second light emitter is in the range of infrared light or visible light.

4. Measuring device according to any of the preceding claims, wherein the reflector is configured as a preferably rectangular, quadratic or semi-circle shaped, thin strip or plate, wherein particularly the length and/or the width dimension of the strip or plate is larger than its thickness, and comprises a color gradation particularly from light to dark, in particular a grey scale gradation, to define the plurality of reflection zones, wherein particularly the color gradient varies continuously along the plurality of reflection zones.

5. Measuring device according to claim 4, wherein the plurality of reflection zones are curved such that the color gradient varies in two directions, particularly being perpendicular to each other, lying in a plane defined by the reflector plate.

6. Measuring device according to any of the preceding claims, wherein the light receiver is configured as a light-emitting diode, particularly a photodiode or phototransistor, wherein particularly the light receiver is designed to receive both the light having the first wavelength λ1 and the light having the second wavelength λ2, wherein in order to distinguish between the received light from the first light emitter and the second light emitter, the first wavelength λ1 differs from the second wavelength λ2, or the first and second light emitters are adapted to perform a chronologically clocked illumination of the reflector.

7. Measuring device according to any of the preceding claims, wherein the first light emitter, the second light emitter and the light receiver are vertically or horizontally preferably evenly distributed, or the first light emitter and the second light emitter are horizontally or vertically spaced to each other and the light receiver is arranged centrally and/or horizontally or vertically spaced with regard to the first and second light emitters.

8. Measuring device according to any of the preceding claims, wherein the processor comprises a software, particularly with an algorithm, to calculate the loading and the vibrations of the washer drum based on the measured light intensities caused by the first and the second relative displacement, wherein the software is able to compare the calculated loading respectively vibrations with predetermined preferably threshold values of the loading respectively vibrations in order to initiate counteractions to prevent the washer drum and the washing machine from damage and/or wearing, wherein particularly the software generates control commands to adjust the amount of water in the washer drum, the rotational speed of the washer drum and/or the drive force.

9. Washing machine comprising:

a washer drum being able to rotate within a washing machine body surrounding the washer drum; and
a measuring device according to any of the preceding claims, wherein the reflector is fixedly mounted to a periphery of the washer drum and the first light emitter, the second light emitter and the light receiver are fixedly mounted on an inner surface of the washing machine body and at least temporarily face the reflector during rotation of the washer drum, or vice versa.

10. Use of a measuring device for determining the loading and the vibrations of a washer drum of a washing machine according to any of the preceding claims.

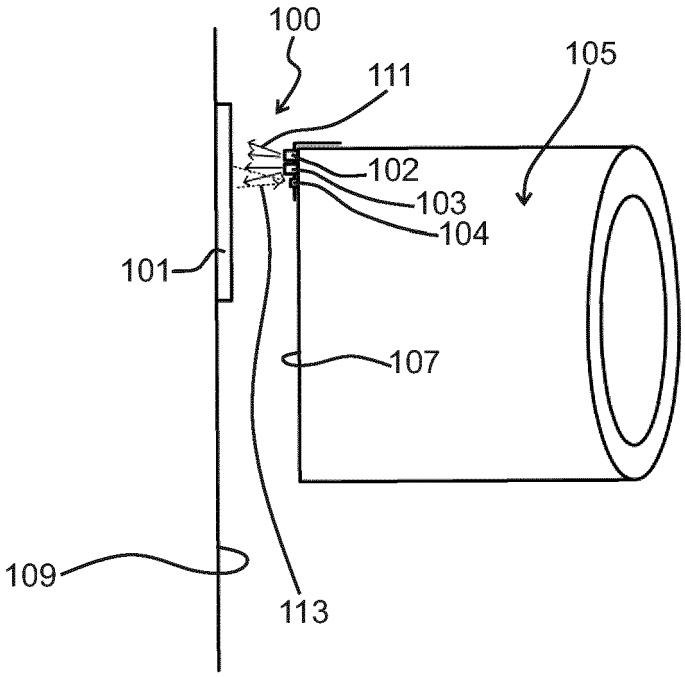
100
111
105
102
103
104
101
107
109
113

Fig. 1A

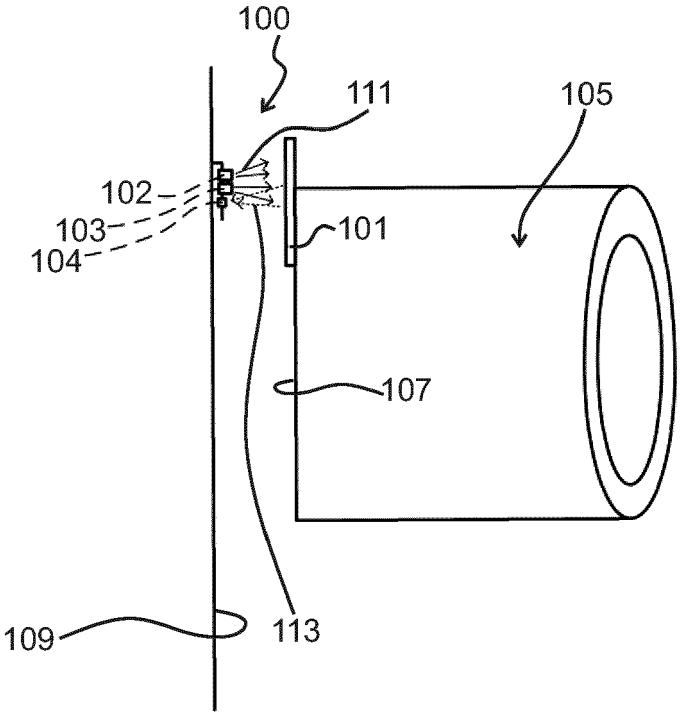
100
111
105
102
103
104
101
107
109
113

Fig. 1B

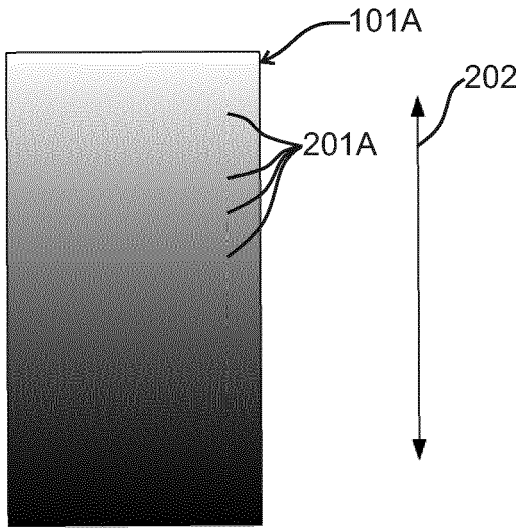

Fig. 2A

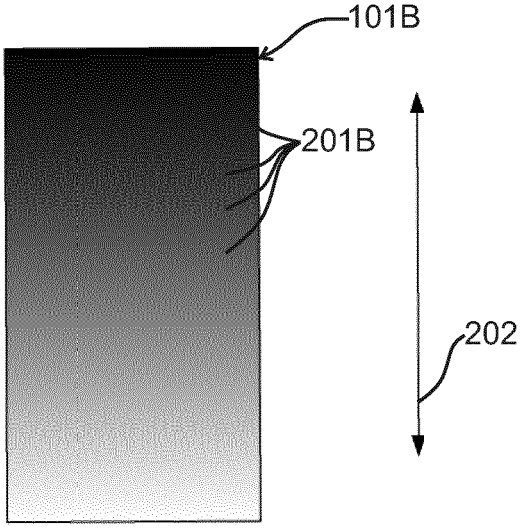

Fig. 2B

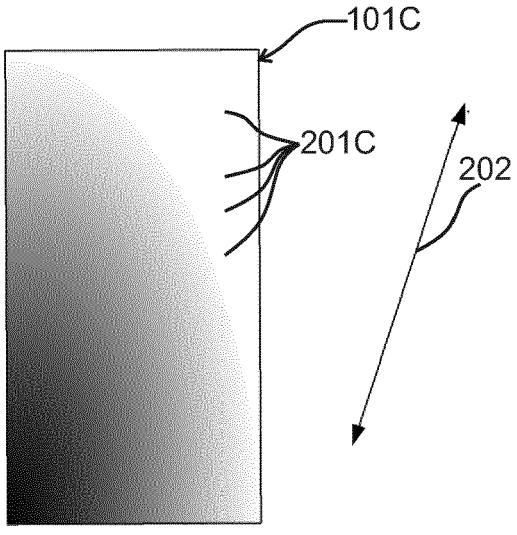

Fig. 2C

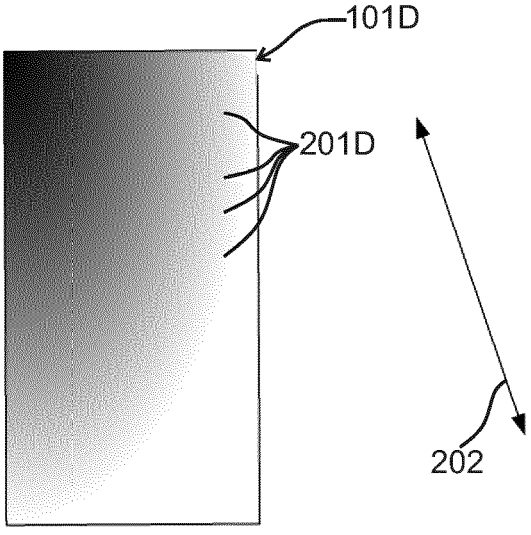

Fig. 2D

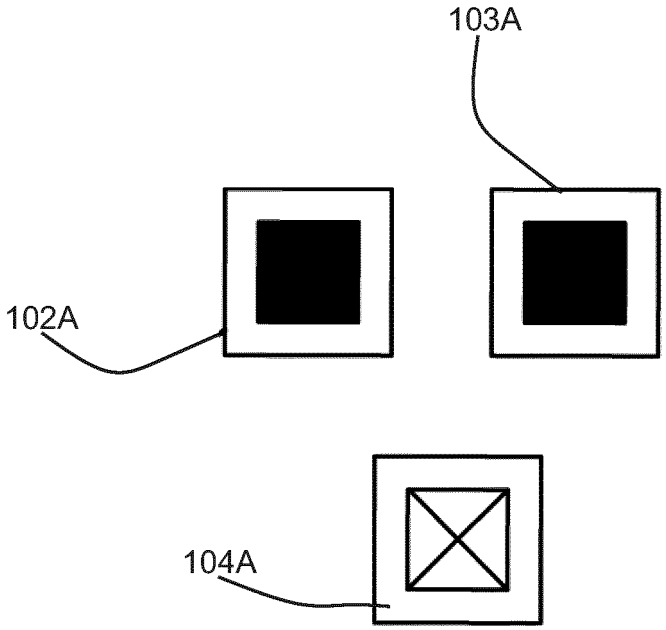

Fig. 3A

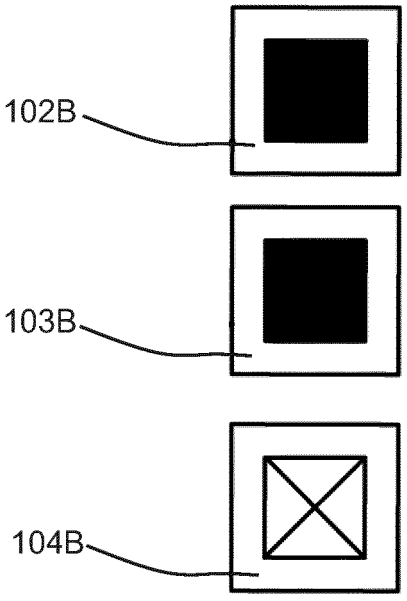

Fig. 3B

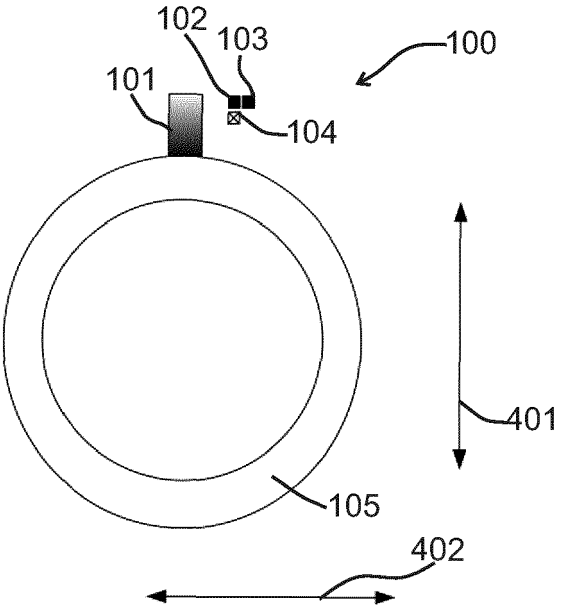
102
103
100
101
104
401
105
402

Fig. 4A

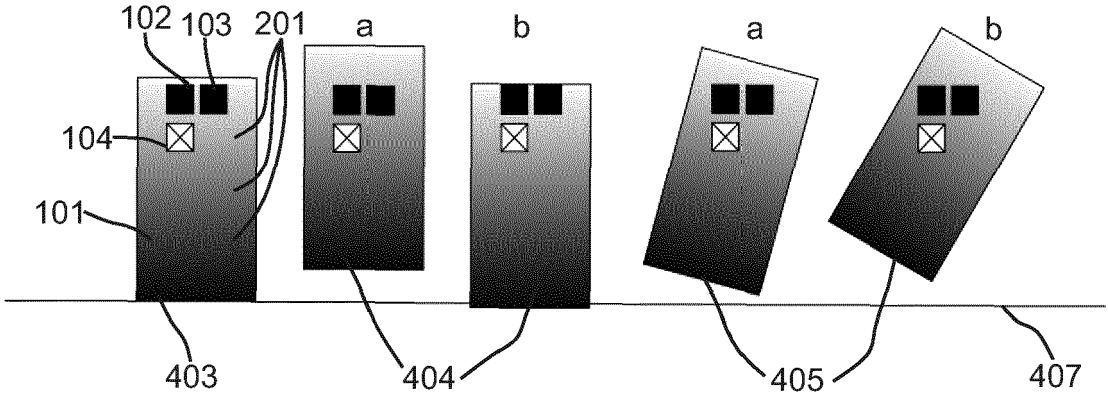
102
103
201
a
b
a
b
104
101
403
404
405
407

Fig. 4B

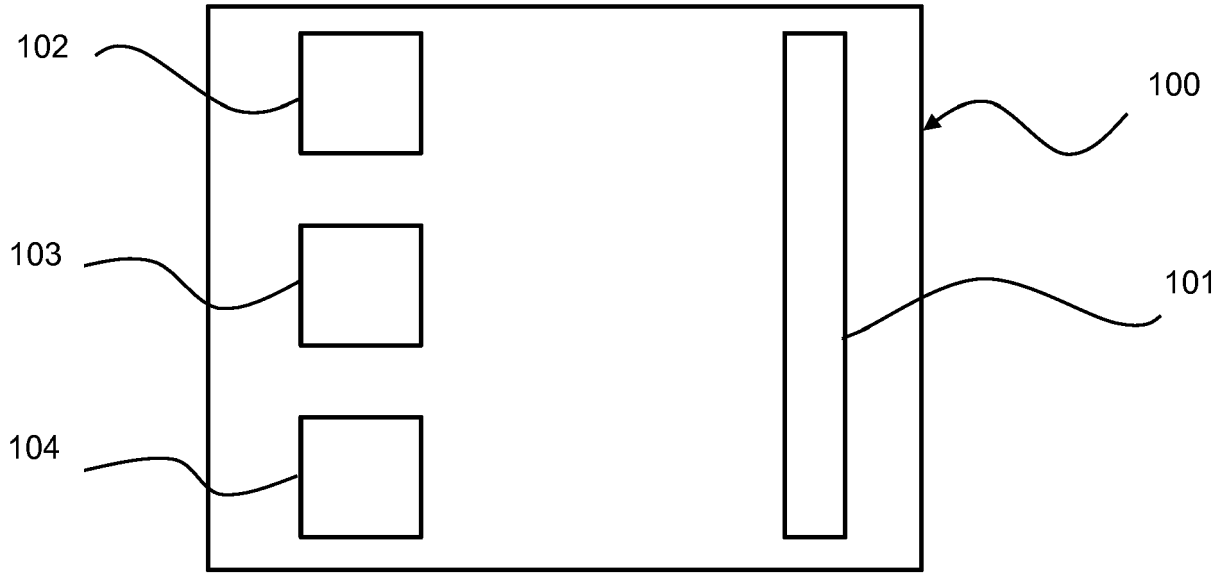

Fig. 5

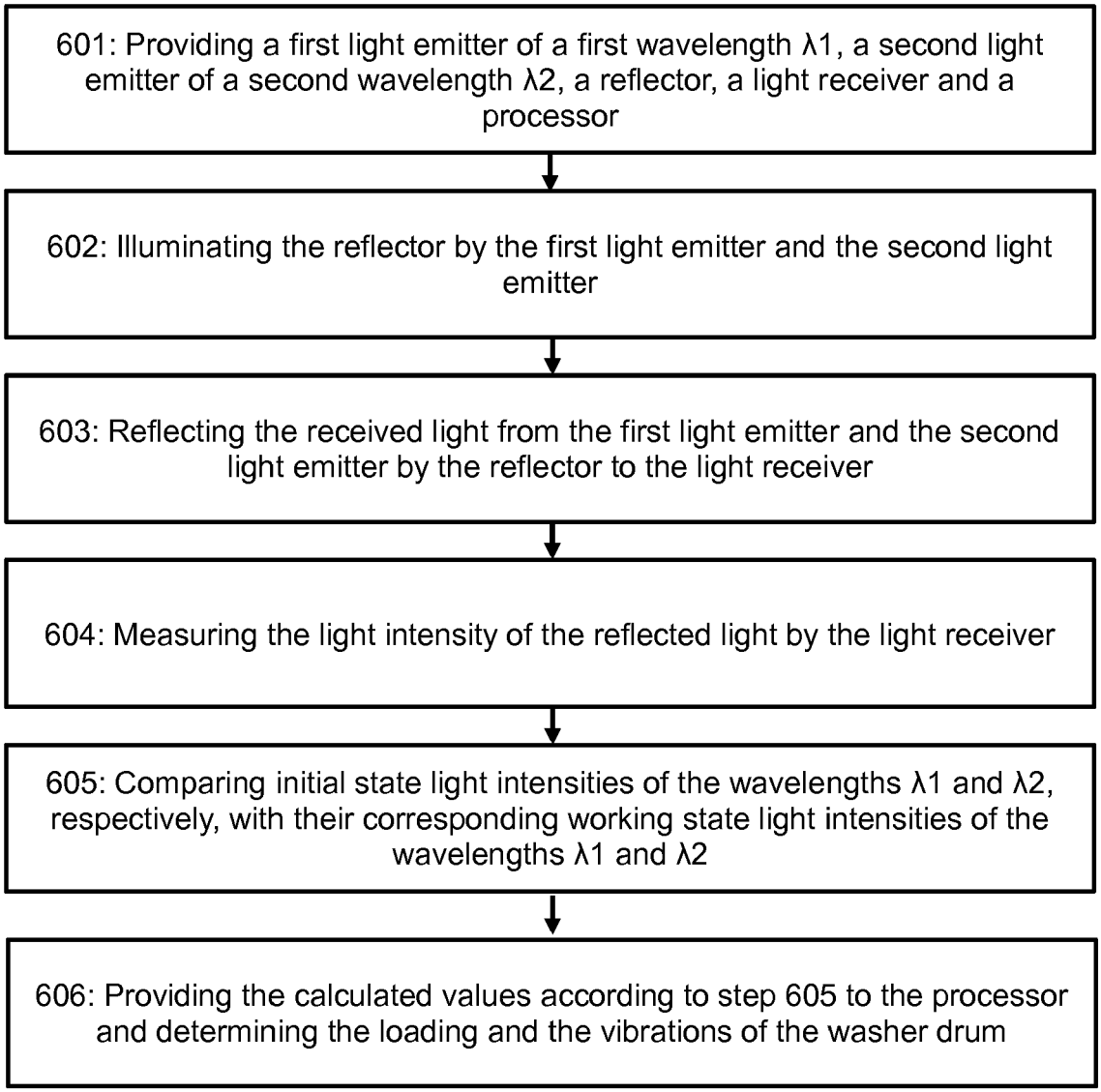
601: Providing a first light emitter of a first wavelength λ1, a second light emitter of a second wavelength λ2, a reflector, a light receiver and a processor
602: Illuminating the reflector by the first light emitter and the second light emitter
603: Reflecting the received light from the first light emitter and the second light emitter by the reflector to the light receiver
604: Measuring the light intensity of the reflected light by the light receiver
605: Comparing initial state light intensities of the wavelengths λ1 and λ2, respectively, with their corresponding working state light intensities of the wavelengths λ1 and λ2
606: Providing the calculated values according to step 605 to the processor and determining the loading and the vibrations of the washer drum

Fig. 6

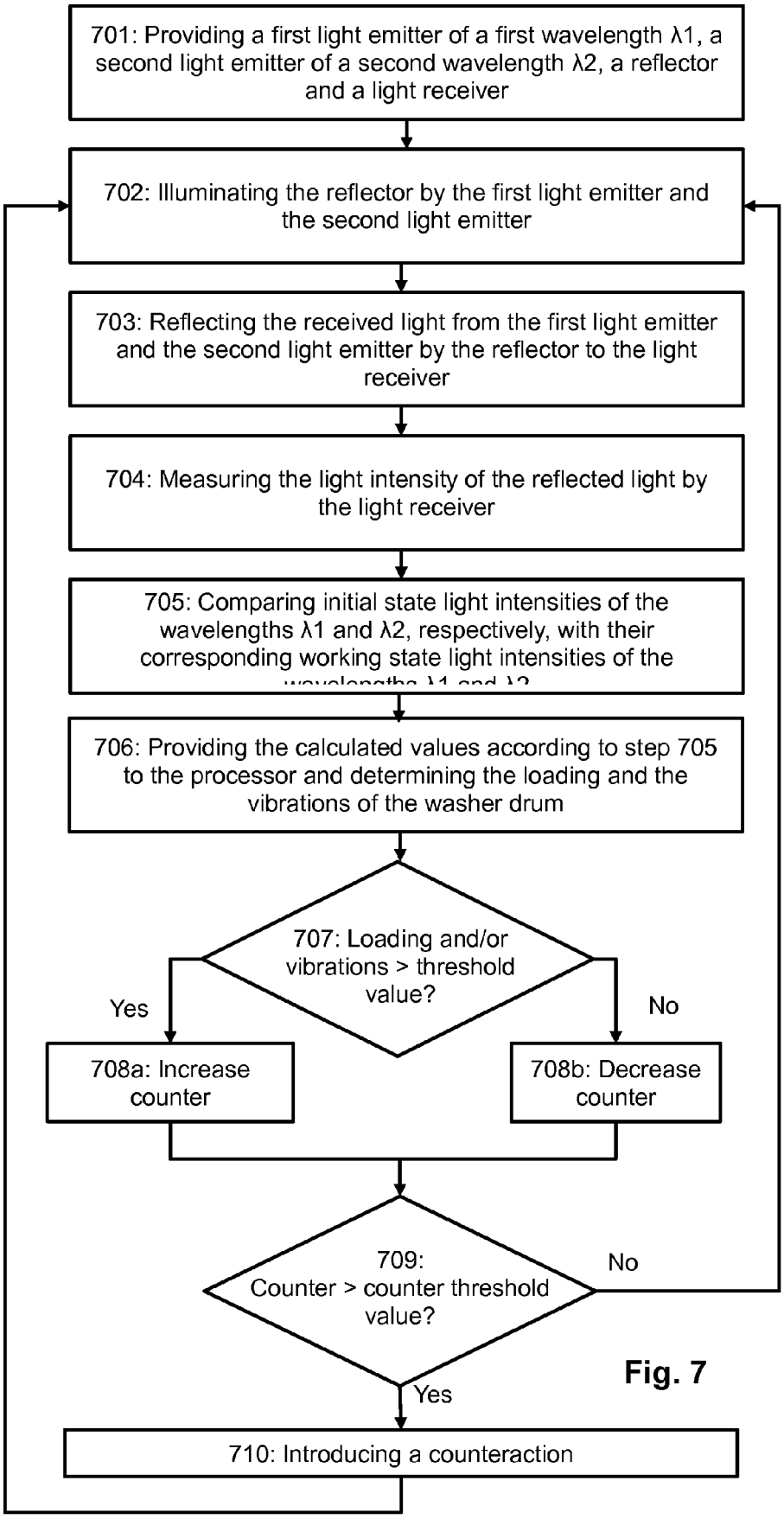
701: Providing a first light emitter of a first wavelength λ1, a second light emitter of a second wavelength λ2, a reflector and a light receiver
702: Illuminating the reflector by the first light emitter and the second light emitter
703: Reflecting the received light from the first light emitter and the second light emitter by the reflector to the light receiver
704: Measuring the light intensity of the reflected light by the light receiver
705: Comparing initial state light intensities of the wavelengths λ1 and λ2, respectively, with their corresponding working state light intensities of the
706: Providing the calculated values according to step 705 to the processor and determining the loading and the vibrations of the washer drum
707: Loading and/or vibrations > threshold value?
Yes
No
708a: Increase counter
708b: Decrease counter
709: Counter > counter threshold value?
No
Yes
710: Introducing a counteraction

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 0069

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	US 5 713 221 A (MYERS SEAN F [US] ET AL) 3 February 1998 (1998-02-03) * column 3, line 60 - column 5, line 14; figures 1,3-6 *	1,4-6, 8-10	INV. D06F39/00 D06F37/20 D06F33/02
A	US 2012/279261 A1 (KA KEE HWAN [KR] ET AL) 8 November 2012 (2012-11-08) * paragraph [0158] - paragraph [0195]; claims; figures 14A,14B,15, 16, 20A,20B *	1,4,6, 8-10	
A	JP H11 276762 A (MATSUSHITA ELECTRIC IND CO LTD) 12 October 1999 (1999-10-12) * abstract; figures 1-12,14 *	1,4,6, 8-10	
A	JP H10 235070 A (SHARP KK) 8 September 1998 (1998-09-08) * abstract; figures 1-10 *	1,4,6, 8-10	

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	7 August 2017	Kising, Axel

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 18 0069

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07-08-2017

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82