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(54) **Method and apparatus for determining an imbalance condition in an appliance**

(57) An appliance and method is provided that can determine load imbalance or out-of-balance conditions. The appliances that typically apply load imbalance detection are clothes washers. A method of imbalance detection includes identifying parameter values that fluctuate with load imbalance over a predetermined sample period (201) and determining a target parameter value from the identified parameter values (202). The method further includes calculating a parameter spread of the parameter values by comparing parameter values to the target parameter value (203). The method further includes converting the parameter spread into a weight value that reflects an imbalance condition.

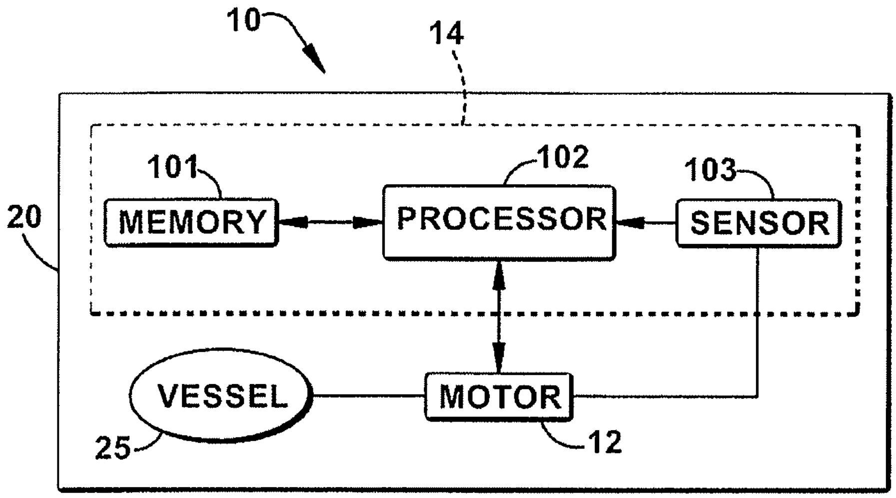

Fig. 2

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Description

BACKGROUND

Field of the Invention

[0001] The present invention generally relates to methods and an apparatus for detecting imbalance conditions in an appliance.

DESCRIPTION OF THE RELATED ART

[0002] Appliances such as automatic washing machines typically contain rotatable vessels that are designed to hold material or clothing and are known in the art. The vessel is contained within a housing and is perforated with apertures. The apertures allow water to be pumped into the vessel to wash the material in the vessel and to allow soiled water to be forced out of the vessel. A washing machine usually contains a main control panel that controls various cycles, typically comprising a wash cycle, spin cycle, a rinse cycle, followed by another spin cycle. Water is pumped into the vessel during the wash cycle and rinse cycle, while it is extracted via centrifugal force during the spin cycle as the vessel rotates or spins. Additionally, a washing machine usually contains an agitator that oscillates to facilitate washing where the vessel rotates about a vertical axis. In machines that contain vessels that rotate about a horizontal axis, an agitator is usually not included as clothes can be tumbled instead of agitated in order to facilitate in the washing process.

[0003] Appliances that contain rotatable vessels are subject to operating conditions such as load imbalances. Load imbalances in appliances such as washing machines occur when the material contained in the vessels is not evenly distributed within the vessel. The material may be unevenly distributed when loaded into the vessel or may become unevenly distributed as the vessel rotates. For example, in vertical-axis washing machines, when a wash or rinse cycle completes and water is drained from the vessel, the clothes are gathered at the bottom of the vessel without being evenly distributed within the vessel. As the motor ramps up the speed for the next cycle, the clothes can creep up the sides of the vessel and become imbalanced.

[0004] Similarly, in horizontal-axis washing machines, load imbalances can occur when clothes are not evenly distributed during the machine's distribution cycle. Load imbalance conditions can cause various inconveniences such as severe vibration and movement of the appliance. Severe vibration occurs when a load is imbalanced, or out of balance because the center of mass of the rotating vessel no longer corresponds to the geometric axis of the vessel. Severe vibration can cause an appliance to move along the surface it rests upon, for example, when a washing machine moves across the floor. Additionally, severe vibration can cause the vessel to break free from its mountings. Another disadvantage of load imbalance conditions is that the motor's power is wasted in the vibrations and movement instead of being fully applied to rotating the vessel.

[0005] Prior art solutions designed to prevent imbalance conditions were typically mechanical and include adding masses to the rotatable vessel of the appliance in order to counter-balance imbalance conditions.

[0006] Other solutions that were designed to detect imbalance conditions are typically complex and include comparing the actual power usage of a vessel to an expected power usage and measuring current ripples. One example of such an attempt is illustrated in U.S. Patent No. 6,640,374, where the amount of current used by the motor to rotate the vessel is compared to a threshold value.

[0007] Accordingly, there is a need to provide an improved method and apparatus to detect load imbalance conditions in an appliance to allow for simplified design and manufacturing.

BRIEF DESCRIPTION OF THE INVENTION

[0008] In one embodiment of the invention, an appliance and method is provided that can determine load imbalance or out-of-balance conditions. The appliances that typically apply load imbalance detection are clothes washers. A method of imbalance detection includes identifying parameter values that fluctuate with load imbalance over a predetermined sample period and determining a target parameter value from the identified parameter values. The method further includes calculating a parameter spread of the parameter values by comparing parameter values to the target parameter value. The method further includes converting the parameter spread into a weight value that reflects an imbalance condition.

[0009] In another embodiment of the invention, a computer program embodied on a computer-readable medium includes identifying parameter values that fluctuate with load imbalance over a predetermined sample period and determining a target parameter value from the identified parameter values. The method further includes calculating a parameter spread of the parameter values by comparing parameter values to the target parameter value. The method further includes converting the parameter spread into a weight value that reflects an imbalance condition.

[0010] In another embodiment of the invention, an appliance includes a vessel mounted for rotation about an axis; a motor for rotating the vessel about an axis; a processor configured to determine load imbalance; and a memory for receiving and storing parameter data and instructions for determining load imbalance. The load imbalance is determined by identifying parameter values that fluctuate with load imbalance over a predetermined sample period and determining a target parameter value from the identified parameter values. The method further includes calculating a parameter spread of the parameter values by comparing parameter values to the target parameter value. The method further includes converting the parameter spread into a weight value that reflects an imbalance condition.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] There follows a detailed description of embodiments of the invention by way of example only with reference to the accompanying drawings in which:

Fig. 1 a is a view of a horizontal-axis washing machine;

Fig. 1b is a diagram showing a horizontal-axis washing machine;

Fig. 2 is a block diagram showing a system for detecting a load imbalance in an embodiment of the present invention;

Fig. 3 is a flow diagram showing a method for detecting a load imbalance condition;

Fig. 4 is a table containing load imbalance data; and

Fig. 5 is a graph of the load imbalance data of Fig. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] One embodiment of the present invention concerns a method and a circuit for detecting a load imbalance in an appliance that is simple to implement.

[0013] Referring now to Fig. 1a, a horizontal-axis washing machine in accordance with one embodiment of the present invention is illustrated generally at 10. A horizontal-axis washing machine includes a vessel that rotates about a horizontal axis within the cabinet. Another embodiment of the invention includes a vertical-axis machine where the vessel rotates about a vertical axis within the cabinet. One of ordinary skill in the art can perform the exemplary embodiments of the invention described herein using either configuration. Washer 10 includes a motor 12 and a motor control unit 14 (see Fig. 1b) that can also be integrated within one unit. Washer 10 includes an outer housing or cabinet 20 supporting a fixed tub 22, a vessel or moving tub ("tub") 25, motor 12, and motor control unit 14, within which there is a processor 102, in a known manner. Vessel drive shaft 30 is also illustrated. Tub 25 is configured to hold articles (not shown) such as clothes to be washed.

[0014] In the horizontal washer configuration, a direct belt drive is configured to transmit rotary motion imparted on a motor shaft 36 by motor 12 to tub 25 via drive belt 29. Fig. 1b illustrates a side view of the exemplary washer of the present invention.

[0015] During a spin cycle, liquid within the articles is removed by the centrifugal force imparted by the spinning vessel and is allowed to exit the basket through apertures (not shown). During the spin cycle, articles or clothing becomes plastered to the wall of tub 25 at a first speed or plaster speed. Plaster refers to the centrifugal force of the spin cycle pushing the clothing against the wall or structure of the basket. The clothes remain positioned by centrifugal force during a time period the first speed or plaster speed to a second speed or maximum speed of the spinning basket. The plastered speed and maximum speed can be determined by one of ordinary skill in the art. Load imbalance conditions can occur when the clothes are unevenly plastered throughout the vessel.

[0016] Fig. 2 depicts a block diagram showing an appliance for detecting a load imbalance in an embodiment of the present invention. The appliance, which could be an automatic washing machine 10, can include a cabinet 20, a vessel 25, a motor 12, and a motor control unit 14 including a memory 101, a processor 102, and a sensor 103. The cabinet 20 contains the vessel 25 that can be loaded with material, for example clothes. The motor 12 drives the vessel and can be directly attached to the vessel by a belt, clutch, or a direct coupling, for example. The motor can be any type, including an induction motor. The sensor 103 can detect the rotation speed of the motor shaft along with other parameters that fluctuate due to load imbalance, such as voltage amplitude, torque and motor current, for example. Any type of sensor can be used, including a hall sensor to detect the rotation speed of the motor shaft. The memory 101 stores the executable instructions for controlling the functions of an appliance. The processor 102 executes the instructions stored in the memory 101. The memory 101 can either be external or internal to the processor. The processor may comprise any type of processor including microcontroller or a microprocessor. The processor 102 executes the instructions to determine when an imbalance condition exists according to the method shown in Fig. 3 and takes corrective action if a sufficiently high imbalance or out of-balance (OOB) condition is detected. The actions taken when a sufficiently high imbalance condition is detected may include stopping the motor, attempts to re-balance the clothes in the tub, or a reduction of the allowed top speed.

[0017] Fig. 3 is a flow diagram showing a method for detecting a load imbalance condition. The method includes selecting a parameter that fluctuates due to load imbalance, in this example, voltage amplitude which is required to maintain a constant speed. The method further includes identifying parameter values in a predetermined sample period 201 and determining a target parameter value 202, which is the average of the parameter values in this example. In one exemplary embodiment, the parameter measured is voltage amplitude, required to maintain a constant speed, which is measured at a fixed interval of time, (i.e. every 50ms) of a pre-determined sample period. The sample period represents the predetermined sample period, the time during which the parameter values are read. The parameter values are stored in a data buffer of predetermined length in memory. If the buffer is full, return to the beginning of the data buffer so the parameter data will overwrite the oldest parameter data. The effect of this method is that of a moving data window or moving sample period.

[0018] In one embodiment, the amplitude required to maintain the current speed is calculated in the microprocessor software. The software increases or decreases voltage amplitude according to input from a speed sensor 103 to maintain a constant speed. The speed sensor 103 may be employed to detect speed fluctuations of the motor shaft 36.

[0019] The method further provides calculating a parameter spread of the parameter values described above 203. The parameter spread is calculated whenever the buffer window is full of parameter values, for example or in another embodiment, whenever a total number of parameter values is reached over a given sample period. Also, several sample periods may be taken over time, which constitutes a moving sample period. In one embodiment of the invention, the parameter spread comprises an average deviation based on the difference between the average of the parameter values in the sample period and a particular parameter value, although other methods of determining parameter spread may be used.

[0020] In accordance with the present embodiment, the processor 102 compares individual parameter values to a the target parameter value to get an average deviation of the parameter spread as shown below:

$$\frac{\sum_{i=1}^{N} | X_i - X |}{N}$$

[0021] The parameter spread shown by the equation above requires calculating the average (X) of the total number of parameter values from the sample period, summing the absolute value of each parameter value (X_i), which can be a real-time reading of the fluctuating parameter, minus the average (X), and dividing the sum by a predetermined number of values. The processor can calculate the average parameter error by retrieving the parameter value data from memory at predetermined intervals.

[0022] Furthermore, the parameter spread may be converted to an actual weight value (Lbs or Kg) 204 that can be used to determine the existence of an imbalance condition 205 by the following equation:

$$\text{OOB Lbs} = \text{Parameter Spread} / \text{Load Constant}$$

[0023] Wherein the load constant is calculated by applying a predetermined linear equation to the current load size in the washing machine tub. The current load size can be determined in various ways as determined by one of ordinary skill in the art, and stored in memory as a weight value (1bs or kg). The slope and offset comprise predetermined values that are constants calibrated using known or predetermined imbalance loads.

$$\text{Load Constant} = (\text{Load Size})\,(\text{Slope}) + \text{Offset}$$

[0024] An example of calibration includes calculating the average deviation for a chosen parameter for each known imbalance load, which is a known actual imbalance that has a weight value (lbs or kg). When voltage is the measured parameter, the voltage deviation is measured as an A/D value, where 1 VDC = 2.0277 A/D units.

[0025] In practical embodiments the load constant may be determined through empirical data that may stored in tabular format in the memory 101. To accomplish this, the load constant may be generated through the use of empirical data such as that provided in Figure 4 utilizing the following equation wherein the parameter spread is the average deviation as provided in Figure 4.

$$\text{Load Constant} = \text{Parameter Spread} / \text{Actual OOB}$$

[0026] When voltage amplitude is the measured parameter, the equation for the load constant can be modified as shown below:

$$\text{Load Constant} = \text{Parameter Spread} * \text{Speed} / \text{Actual OOB}$$

[0027] The modification to the equation includes multiplying the parameter spread by the speed of the motor in order to normalize the voltage amplitude spread. The modification to the equation above is not required, although desirable due to the drop in amplitude spread as speed increases. If the amplitude spread is multiplied by the speed, the resulting load constant curve is flatter and provides an improved imbalance calculation. In the current implementation, the OOB calculation is optimized between 90 basket RPM (or plaster speed) and about 150 basket RPM. This range may vary slightly based on machine dynamics.

[0028] Referring now to Fig. 5, a linear graph of the data from the table of Fig. 4 showing slope 300 gives the equation:

$$\text{Load Constant} = -7.2623 * \text{Load Size} + 152.46$$

[0029] Wherein the load size is the actual weight of the clothes in the vessel.

[0030] The imbalance weight value (OOB Lbs) can be determined by the using the equation:

$$\text{OOB} = \text{Parameter Spread} / \text{Load Constant}$$

[0031] An imbalance condition will be detected when the OOB value is above a predetermined value.

[0032] The particular embodiments of the invention described above are merely illustrative as the invention may be practiced in different but equivalent manners apparent to those skilled in the art. Similarly, the protection sought is to be found in the claims and is not to be limited by the descriptions of the embodiments above. Therefore, the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope of the invention.

[0033] For completeness, various aspects of the invention are now set out in the following numbered clauses:

1. A method for determining an imbalance condition in an appliance, comprising:

   identifying parameter values that fluctuate with load imbalance over a predetermined sample period;

   determining a target parameter value from the identified parameter values;

   calculating a parameter value spread of the parameter values by comparing parameter values to the target parameter value;

   converting said parameter spread into a weight value that reflects an imbalance condition.

2. The method of clause 1 wherein the predetermined sample period comprises a moving sample period.

3. The method of clause 1 wherein the target parameter value comprises an average.

4. The method of clause 1, further comprising periodically recalculating the target parameter value and identifying additional parameter values.

5. The method of clause 1 wherein calculating said parameter value spread comprises:

calculating an average parameter value from said parameter values; and

comparing said average parameter value to each said parameter value to arrive at an average deviation value;

6. The method of clause 1 wherein converting said parameter spread into a weight value comprises:

dividing said parameter spread by a load constant value.

7. The method of clause 6, wherein said parameter spread is multiplied by current motor speed.

8. The method of clause 1, wherein the said parameter value comprises speed.

9. The method of clause 1, wherein the said parameter value comprises voltage amplitude required to maintain a constant speed.

10. The method of clause 1, wherein said appliance is an automatic washing machine.

11. The method of clause 1, wherein said washing machine is a horizontal axis washer.

12. The method of clause 1, wherein said washing machine is a vertical axis washer.

13. A computer program embodied on a computer-readable medium, comprising:

identifying parameter values that fluctuate with load imbalance over a predetermined sample period;

determining a target parameter value from the identified parameter values;

calculating a parameter value spread of the parameter values by comparing parameter values to the target parameter value;

converting said parameter spread into a weight value that reflects an imbalance condition.

14. An appliance comprising:

a vessel mounted for rotation about an axis;

a motor for rotating the vessel about an axis;

a processor configured to determine load imbalance; and

a memory for receiving and storing parameter data and instructions for determining load imbalance;

wherein the load imbalance is determined by:

identifying parameter values that fluctuate with load imbalance over a predetermined sample period;

determining a target parameter value from the identified parameter values;

calculating a parameter value spread of the parameter values by comparing parameter values to the target parameter value;

converting said parameter spread into a weight value that reflects an imbalance condition.

15. The device of clause 14 wherein the predetermined sample period comprises a moving sample period.

16. The device of clause 14 wherein the target parameter value comprises an average.

17. The device of clause 14, wherein the load imbalance is further determined by periodically recalculating the target parameter value and identifying additional parameter values.

18. The device of clause 14 wherein calculating said parameter value spread comprises:

calculating an average parameter value from said parameter values; and

comparing said average parameter value to each said parameter value to arrive at an average deviation value;

19. The device of clause 14 wherein converting said parameter spread into a weight value comprises:

dividing said parameter spread by a load constant value based on the weight of the load in a washer.

20. The device of clause 14, wherein said parameter spread is multiplied by current motor speed.

21. The device of clause 14, wherein the said parameter value comprises speed.

22. The device of clause 14, wherein the said parameter value comprises voltage amplitude required to maintain a constant speed.

23. The device of clause 14, wherein said appliance is a washing machine.

24. The device of clause 23, wherein said appliance is a horizontal axis washer.

25. The device of clause 23, wherein said appliance is a vertical axis washer.

Claims

1. A method for determining an imbalance condition in an appliance, comprising:

identifying parameter values that fluctuate with load imbalance over a predetermined sample period (201);
determining a target parameter value from the identified parameter values (202);
calculating a parameter value spread of the parameter values by comparing parameter values to the target parameter value (203);
converting said parameter spread into a weight value that reflects an imbalance condition.

2. The method of claim 1 wherein the predetermined sample period comprises a moving sample period and wherein the target parameter value comprises an average.

3. The method of claim 1 or 2, further comprising periodically recalculating the target parameter value and identifying additional parameter values.

4. The method of any of the preceding claims, wherein calculating said parameter value spread comprises:

calculating an average parameter value from said parameter values (203); and comparing said average parameter value to each said parameter value to arrive at an average deviation value;

5. The method of any of the preceding claims, wherein converting said parameter spread into a weight value comprises:

dividing said parameter spread by a load constant value.

6. An appliance comprising:

a vessel (25) mounted for rotation about an axis;
a motor(12) for rotating the vessel about an axis;
a processor (102) configured to determine load imbalance; and
a memory (101) for receiving and storing parameter data and instructions for determining load imbalance;
wherein the load imbalance is determined by:
identifying parameter values that fluctuate with load imbalance over a predetermined sample period (201);
determining a target parameter value from the identified parameter values (202);
calculating a parameter value spread of the parameter values by comparing parameter values to the target parameter value (203);
converting said parameter spread into a weight value that reflects an imbalance condition.

7. The device of claim 6 wherein the predetermined sample period comprises a moving sample period and wherein the target parameter value comprises an average.

8. The device of claim 6 or 7, wherein the load imbalance is further determined by periodically recalculating the target parameter value and identifying additional parameter values.

9. The device of any of claims 6 to 8, wherein calculating said parameter value spread comprises:

calculating an average parameter value from said parameter values; and comparing said average parameter value to each said parameter value to arrive at an average deviation value.

10. The device of any of claims 6 to 9, wherein converting said parameter spread into a weight value comprises:

dividing said parameter spread by a load constant value based on the weight of the load in a washer.

11. The device of any of claims 6 to 10, wherein said parameter spread is multiplied by current motor speed.

12. The device of any of claims 6 to 11, wherein the said parameter value comprises speed.

13. The device of any of claims 6 to 12, wherein the said parameter value comprises voltage amplitude required to maintain a constant speed.

14. The device of any of claims 6 to 13, wherein said appliance is a washing machine.

15. The device of claim 14, wherein said appliance is a horizontal axis washer.

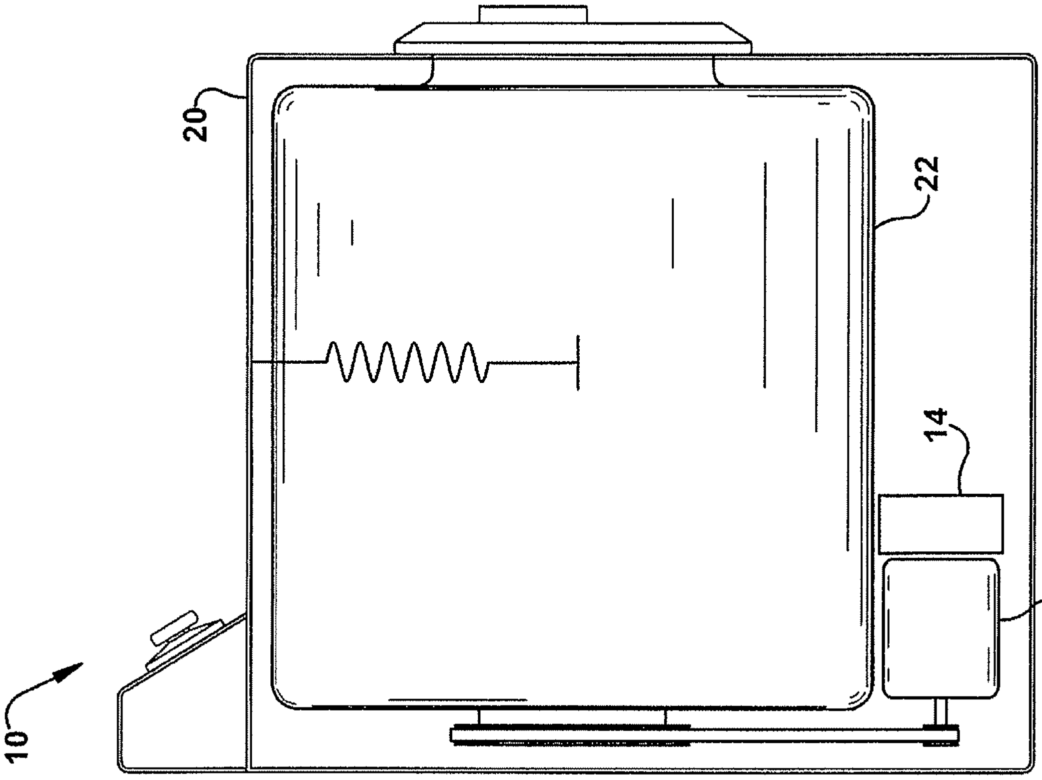

Fig. 1b

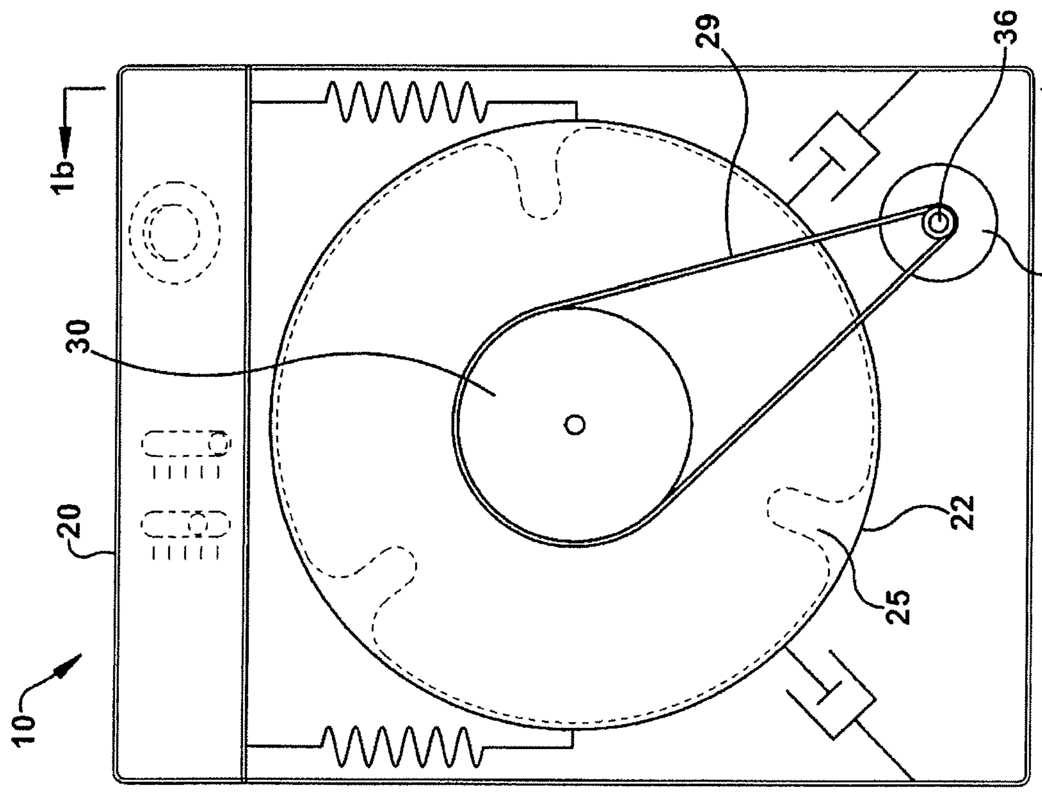

Fig. 1a

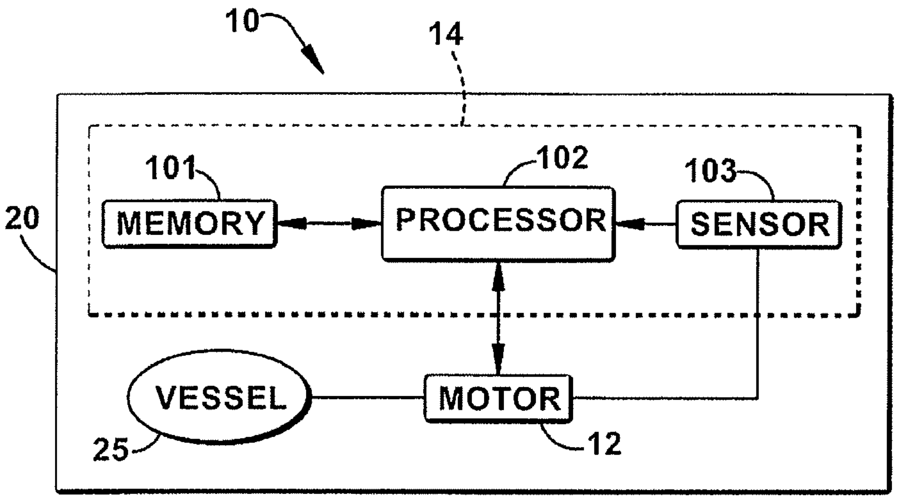
10
14
20
101
MEMORY
102
PROCESSOR
103
SENSOR
VESSEL
MOTOR
25
12

Fig. 2

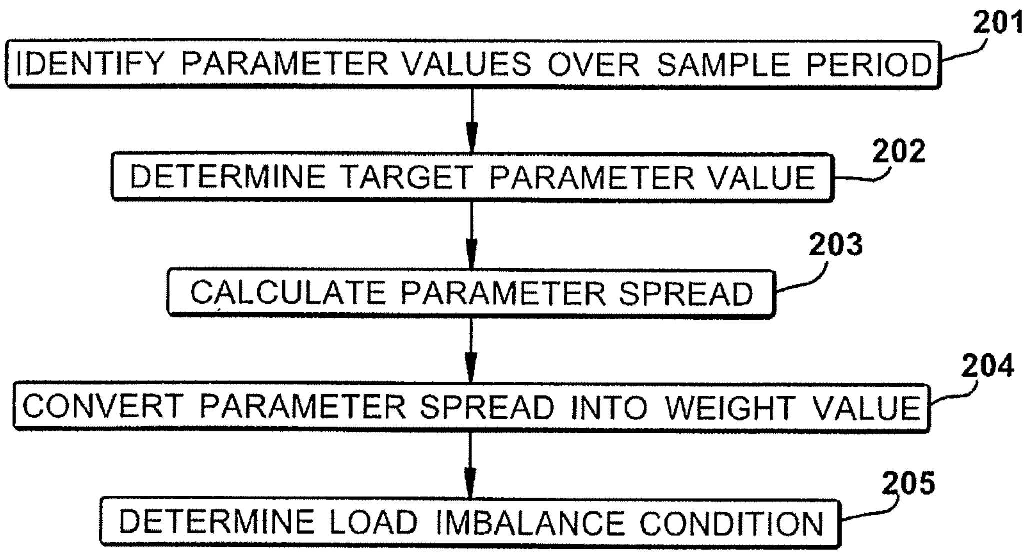
IDENTIFY PARAMETER VALUES OVER SAMPLE PERIOD
201
DETERMINE TARGET PARAMETER VALUE
202
CALCULATE PARAMETER SPREAD
203
CONVERT PARAMETER SPREAD INTO WEIGHT VALUE
204
DETERMINE LOAD IMBALANCE CONDITION
205

Fig. 3

AVERAGE DEVIATION	ACTUAL OOB (lbs)	CALCULATED LOAD CONSTANT
13	0	N/A
68	0.498	136.6
136	0.989	137.5
202	1.47	137.4
370	3.053	121.2
21	0	N/A
41	0.496	82.7
82	0.989	82.9
117	1.47	79.6
226	2.947	76.7
37	0	N/A
36	0.496	72.6
59	0.989	59.7
73	1.47	49.7
154	2.944	52.3

Fig. 4

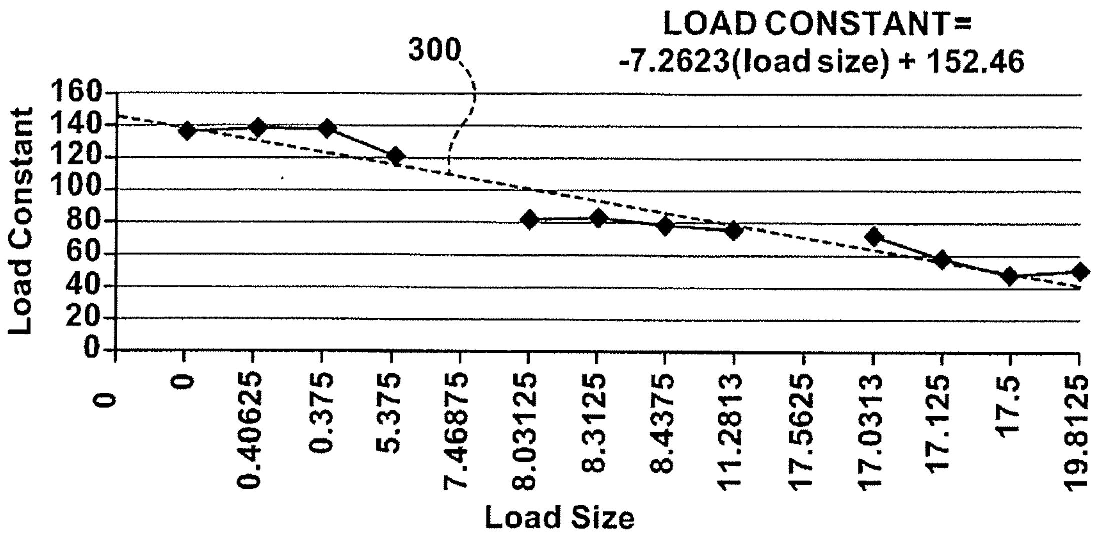

Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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