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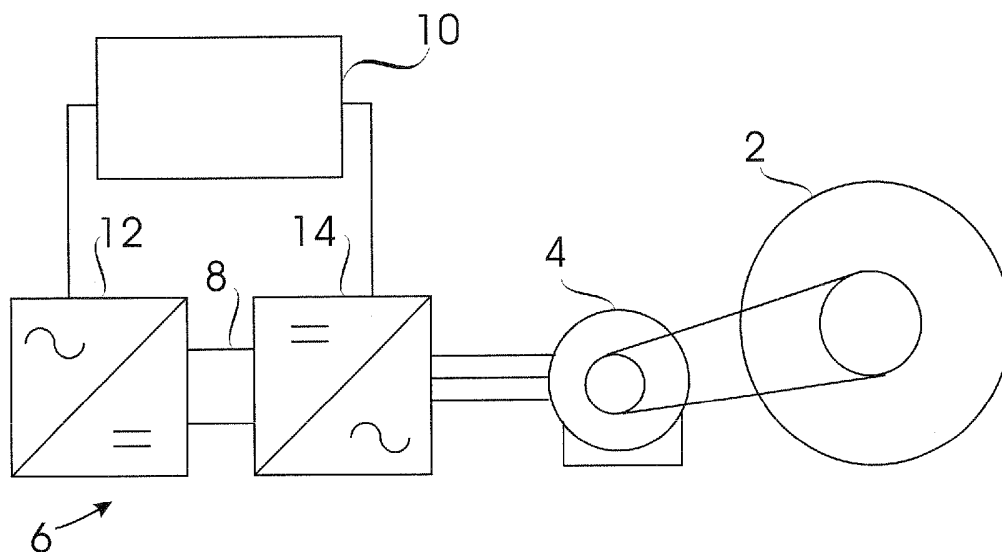
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(54) Title: CONFIGURATION AND METHOD FOR DETERMINING UNBALANCE OF ROTATING DRUM



(57) Abstract: A configuration for determining unbalance of a rotating drum, the configuration comprising a rotating drum (2), an electric motor (4) configured to rotate the rotating drum (2), a frequency converter (6) configured to feed electric power to the motor (4), and data processing means (10). The data processing means (10) are configured to divide current of the motor (4) into a component (I_d) relating to magnetization of the motor and into a component (I_q) relating to a torque of the motor, and to determine the unbalance of the rotating drum on the basis of information which is related to the rotation of the motor and obtained by means of a computational motor model.

CONFIGURATION AND METHOD FOR DETERMINING UNBALANCE OF ROTATING DRUM

BACKGROUND OF THE INVENTION

[0001] The invention relates to a configuration and method for determining unbalance of a rotating drum in accordance with the preambles of the independent claims.

[0002] In configurations which comprise a rotating drum arranged to receive material therein, it is often useful to determine the unbalance of the drum. As far as the operation of washing machines is concerned, for example, it is advantageous that laundry should be evenly distributed over the inner surface of the drum of a washing machine. The more evenly the laundry is distributed, the less oscillatory the operation of the washing machine during spin drying.

[0003] Methods exist for distributing laundry evenly onto the surface of a washing machine, but the results of these methods must be checked by an appropriate method for detecting unbalance. It is known to detect unbalance of a washing machine on the basis of variations in the rotation speed and torque of a motor of the washing machine caused by irregularly distributed laundry.

[0004] In most known configurations, in order to determine the unbalance of a rotating drum, measurement of the rotation speed of the drum or the motor rotating the drum is used. It is, however, known to determine the unbalance of a rotating drum also without measuring the rotation speed. A known configuration for determining the unbalance of a rotating drum without measuring the rotation speed is disclosed in publication EP 1 067 230 A2.

[0005] In the known configurations, wherein the unbalance of a rotating drum is determined without measuring the rotation speed, a problem is the inaccuracy thereof as compared with configurations utilizing rotation speed measurement.

BRIEF DESCRIPTION OF THE INVENTION

[0006] An object of the invention is to provide a configuration which enables unbalance of a drum rotated by means of an electric motor fed by a frequency converter to be determined more accurately without measuring a rotation speed. The object of the invention is achieved by a configuration which

is characterized by what is disclosed in independent claim 1. Preferred embodiments of the invention are disclosed in the dependent claims.

[0007] Another object of the invention is to provide a more accurate method of determining unbalance of a drum rotated by means of an electric motor fed by a frequency converter without measuring a rotation speed. The object of the invention is achieved by a method which is characterized by what is disclosed in the independent method claim.

[0008] An idea underlying the invention is that the unbalance of a drum rotated by means of an electric motor fed by a vector-controlled frequency converter is determined on the basis of information which is related to the rotation of the motor and obtained by means of a computational motor model formed for the electric motor rotating the drum.

[0009] An advantage of the configuration and method in accordance with the invention is a more accurate determination of the unbalance of a rotating drum without measuring a rotation speed.

DETAILED DESCRIPTION OF THE INVENTION

[0010] The invention is now described in closer detail in connection with a preferred embodiment and with reference to Figure 1, which is a schematic view showing an embodiment of a configuration according to the invention.

[0011] The configuration of Figure 1 comprises a rotating drum 2, an electric motor 4, a frequency converter 6, and data processing means 10. The electric motor 4 is configured to rotate the drum 2, the frequency converter 6 is configured to feed electric power to the motor 4, and the data processing means 10 are configured to determine the unbalance of the rotating drum. The frequency converter 6 comprises a rectifier 12, an inverter 14, and a direct voltage intermediate circuit 8 electrically located therebetween.

[0012] The data processing means 10 are configured to determine the unbalance of the rotating drum 2 by using instantaneous electric variables measured from the electric motor 4 and/or the frequency converter 6 as well as a computational motor model of the electric motor 4. The computational motor model determines information relating to the rotation of the electric motor 4 by using the aforementioned instantaneous electric variables as source information.

[0013] The instantaneous electric variables used as the source information in the computational motor model for determining unbalance may, in addition to the current of the motor 4, comprise e.g. the voltage of the direct voltage intermediate circuit 8. The current of the motor 4 and the voltage of the direct voltage intermediate circuit 8 can be determined by using a known technique. The current of the motor 4 can be determined e.g. from the motor output of the frequency converter 6, in connection with power switches of the frequency converter 6, or from the direct voltage intermediate circuit 8 of the frequency converter 6.

[0014] The basics of the computational motor model are disclosed e.g. in "The principle of field orientation as applied to the new TRANSVECTOR closed-loop control system for rotating-field machines" by Blaschke, F. (1972), Siemens Rev., 34(5), pp. 217 to 220. The configuration of the present invention may utilize e.g. a motor model similar to that disclosed in the aforementioned publication.

[0015] The computational motor model used for the configuration of Figure 1 is an adaptive motor model. Adaptivity of a motor model means that the model is maintained, i.e. corrected, prior to and/or during operation by means of measured electric variables. These electric variables measured prior to and/or during operation may comprise the current of the motor 4 and the voltage of the direct voltage intermediate circuit 8. Measurements carried out before operation herein refer to measurements carried out during identification run, such measurements being carried out only once prior to putting the configuration to use. The adaptive motor model can be formed on the basis of type plate values of the motor and other quantities determined from the motor, such as the stator resistance and moment of inertia of the motor.

[0016] The data processing means 10 are configured to divide the current of the motor 4 into a component I_d relating to magnetization of the motor and into a component I_q relating to the torque of the motor, in other words the motor drive of the configuration is a so-called vector-controlled motor drive. By means of the current component I_q relating to the torque of the motor, the data processing means 10 are able to determine the torque of the motor. Vector control methods and methods for determining a torque by means of the current component I_q relating to the torque are widely known in the art, so they will not be explained herein.

[0017] The electric motor 4 may be e.g. a short circuit motor or a permanent magnet synchronous motor. Advantages of a permanent magnet synchronous motor include small size and small weight as well as good efficiency. A further advantage of the permanent magnet synchronous motor is that its rotation speed is continuously completely known.

[0018] The unbalance of a drum 2 rotated by an asynchronous machine can be determined on the basis of rotation speed oscillation and torque oscillation when the drum 2 is rotated at a steady speed. Alternatively, the unbalance of the drum 2 can be determined e.g. on the basis of oscillation of a product of the rotation speed and the torque. The aforementioned methods of determining unbalance are widely known in the art.

[0019] When the motor 4 is a synchronous motor, its rotation speed is easy to keep constant, in which case the unbalance of the drum 2 can be determined using the torque oscillation only. Alternatively, the unbalance can be determined by observing oscillation of a load angle of the synchronous motor. When determining unbalance, it is further possible to utilize both the torque oscillation and the load angle oscillation. A load angle can be determined by means of the data processing means 10, using a computational motor model. A torque, in turn, can be determined by means of the load angle.

[0020] In addition to the unbalance of the rotating drum 2, it is often necessary to determine a moment of inertia of the rotating drum 2. The moment of inertia of the drum can be used for determining rotation speed oscillation and torque oscillation corresponding to a limit value of the unbalance of the drum. The larger the moment of inertia, the smaller the amplitude of rotation speed oscillation and torque oscillation that is to be taken into account. The limit value of unbalance can be selected e.g. on the basis of the maximum permissible vibration for the configuration. In addition to the determination of the limit value of unbalance for the drum, the moment of inertia of the drum or a combined moment of inertia of the drum and the motor can also be utilized in other tasks relating to control of the configuration.

[0021] The moment of inertia is determined on the basis of a torque necessary for acceleration and a torque necessary at constant speed. The torque necessary at constant speed is determined both before and after said acceleration. The determination of a moment of inertia by means of torque values and angular acceleration α during acceleration is widely known.

[0022] In the configuration of Figure 1, the motor 4 rotates the drum 2 through a belt. Alternatively, the motor may rotate the drum e.g. through a chain, transmission or an axle. A motor rotating a drum through an axle may be a so-called direct drive motor.

[0023] The configuration of the invention enables the unbalance of a rotating drum, without measuring a rotation speed, to be determined more accurately than by means of a scalar-controlled configuration. This is achieved by providing a closed loop speed control by using a torque and a rotation speed of the motor, determined by means of a computational motor model. The configuration of the invention may, however, be provided with rotation speed measurement, if necessary, in which case it is possible to determine the unbalance of a rotating drum even more accurately.

[0024] The configuration of the invention may be used e.g. in a washing machine, in which case the configuration is configured to determine the unbalance caused by laundry inserted in the drum of the washing machine. A purpose may be to determine a maximum possible spin drying speed such that the vibration of the washing machine does not exceed a predetermined limit value.

[0025] In the above description, unbalance of a rotating drum simply refers to a situation wherein one side of the drum is more heavily loaded with mass than the other. The unbalance thus refers to any excessive mass residing on one side of a drum.

[0026] The data processing means can be configured to process the unbalance of a drum also by means of variables other than mass describing unbalance. As stated above, unbalance can be described e.g. on the basis of the amplitude of oscillation caused by the unbalance to the rotation speed and the torque, or to a load angle value. When desired, the unbalance of a drum may thus be processed in the data processing means completely without describing the unbalance by a unit of mass.

[0027] It is apparent to a person skilled in the art that the basic idea of the invention can be implemented in many different ways. The invention and its embodiments are thus not restricted to the above-described examples but may vary within the scope of the claims.

CLAIMS

1. A configuration for determining unbalance of a rotating drum, the configuration comprising a rotating drum (2), an electric motor (4) configured to rotate the rotating drum (2), a frequency converter (6) configured to feed electric power to the motor (4), and data processing means (10), **characterized** in that the data processing means (10) are configured to divide current of the motor (4) into a component (I_d) relating to magnetization of the motor and into a component (I_q) relating to a torque of the motor, and to determine the unbalance of the rotating drum on the basis of information which is related to the rotation of the motor and obtained by means of a computational motor model.

2. A configuration as claimed in claim 1, **characterized** in that the data processing means (10) are configured to determine the torque of the motor (4) by means of the current component (I_q) relating to the torque of the motor.

3. A configuration as claimed in claim 1 or 2, **characterized** in that the motor (4) is an asynchronous motor, such as a short circuit motor, and the information relating to the rotation of the motor comprises a computational rotation speed of the motor (4), determined by means of the computational motor model.

4. A configuration as claimed in claim 3, **characterized** in that the unbalance of the rotating drum (2) is determined on the basis of rotation speed oscillation and torque oscillation, or on the basis of oscillation of a product of the rotation speed and the torque.

5. A configuration as claimed in claim 1 or 2, **characterized** in that the motor (4) is a synchronous motor, such as a permanent magnet synchronous motor, and the information relating to the rotation of the motor comprises a computational load angle of the motor (4), determined by means of the computational motor model.

6. A configuration as claimed in claim 5, **characterized** in that when determining the unbalance of the rotating drum (2), observation of computational load angle oscillation and/or torque oscillation of the motor is utilized.

7. A configuration as claimed in any one of the preceding claims, **characterized** in that the computational motor model is an adaptive

motor model, which is corrected prior to and/or during operation by means of measured electric variables.

8. A configuration as claimed in any one of the preceding claims, **characterized** in that the data processing means (10) are further configured to determine a total moment of inertia of the rotating drum (2), i.e. a combined moment of inertia of the drum and the material therein, by using the torque of the electric motor (4), determined by means of the current component (I_q) relating to the torque of the motor, and the computational rotation speed of the electric motor (4).

9. A washing machine, **characterized** in that it comprises a configuration according to any one of the preceding claims.

10. A method of determining unbalance of a rotating drum when the drum (2) is rotated by an electric motor (4) fed by a frequency converter (6), the method comprising a step of

determining current of the electric motor (4) rotating the rotating drum (2), **characterized** in that the method further comprises steps of

dividing the current of the motor (4) into a component (I_d) relating to magnetization of the motor and into a component (I_q) relating to a torque of the motor, and

determining the unbalance of the rotating drum (2) on the basis of information which is related to the rotation of the motor (4) and obtained by means of a computational motor model.

11. A method as claimed in claim 10, **characterized** in that the motor (4) is an asynchronous motor, and the information relating to the rotation of the motor comprises a computational rotation speed of the motor (4), determined by means of the computational motor model, and the unbalance of the rotating drum (2) is determined on the basis of rotation speed oscillation and torque oscillation, or on the basis of oscillation of a product of the rotation speed and the torque.

12. A method as claimed in claim 10, **characterized** in that the motor (4) is a synchronous motor, and the information relating to the rotation of the motor comprises a computational load angle of the motor (4), determined by means of the computational motor model, and when determining the unbalance of the rotating drum (2), observation of oscillation of the computational load angle of the motor and/or oscillation of the torque of the motor is utilized.

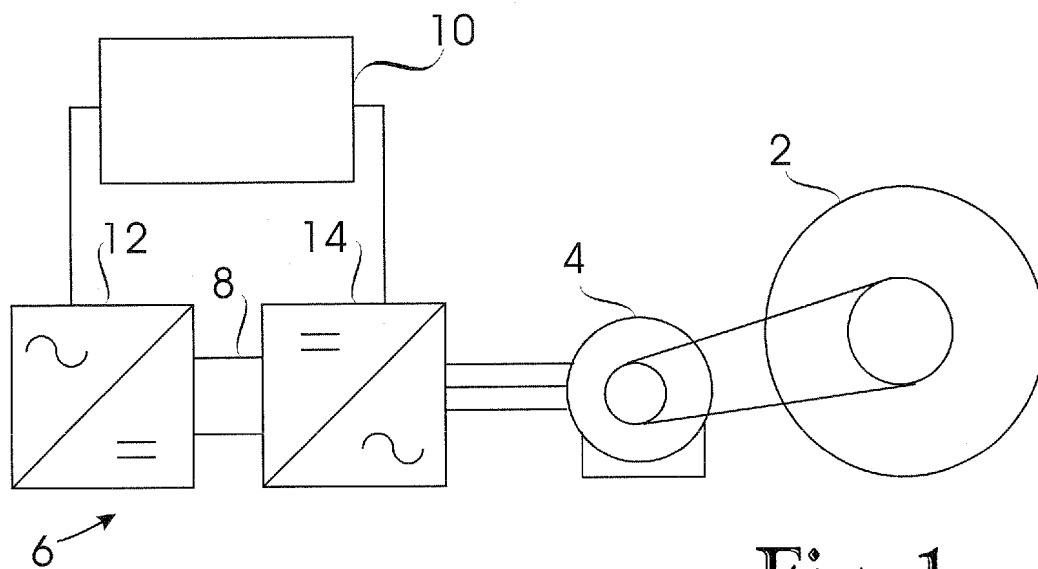


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2005/050358

A. CLASSIFICATION OF SUBJECT MATTER
D06F37/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/009899 A (KABUSHIKI KAISHA TOSHIBA) 29 January 2004 (2004-01-29) & EP 1 548 169 A paragraphs '0022! - '0034!; figures 1,2	1-12
X	EP 0 903 845 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD) 24 March 1999 (1999-03-24) paragraphs '0162! - '0215!; figures 10,14,18,21	1-12
X	EP 1 265 351 A (KABUSHIKI KAISHA TOSHIBA) 11 December 2002 (2002-12-11) paragraphs '0017! - '0034!; figures 1,2	1-12

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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