

(19)



(11)

EP 4 036 300 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
21.01.2026 Bulletin 2026/04

(21) Application number: **22164092.3**

(22) Date of filing: **02.03.2020**

(51) International Patent Classification (IPC):

D06F 33/76 ^(2020.01) **D06F 34/16** ^(2020.01)
D06F 58/52 ^(2020.01) **D06F 103/24** ^(2020.01)
D06F 103/46 ^(2020.01) **D06F 105/62** ^(2020.01)
D06F 105/48 ^(2020.01) **D06F 105/52** ^(2020.01)

(52) Cooperative Patent Classification (CPC):

D06F 33/76; D06F 34/16; D06F 58/52;
D06F 2103/24; D06F 2103/46; D06F 2105/48;
D06F 2105/52; D06F 2105/62

(54) **METHOD TO ESTIMATE A LOAD BEHAVIOR IN A LAUNDRY TREATMENT MACHINE AND LAUNDRY TREATMENT MACHINE**

VERFAHREN ZUR SCHÄTZUNG EINES LASTVERHALTENS IN EINER
WÄSCHEBEHANDLUNGSMASCHINE UND WÄSCHEBEHANDLUNGSMASCHINE

PROCÉDÉ D'ESTIMATION DE COMPORTEMENT D'UNE CHARGE DANS UNE MACHINE DE
TRAITEMENT DE LINGE ET MACHINE DE TRAITEMENT DE LINGE

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(43) Date of publication of application:
03.08.2022 Bulletin 2022/31

(62) Document number(s) of the earlier application(s) in
accordance with Art. 76 EPC:
20160332.1 / 3 875 661

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US-A1- 2019 112 745

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Description

[0001] The invention relates to a method to estimate a load behavior in a laundry treatment machine. Furthermore, the invention relates to a laundry treatment machine with a control unit to estimate a load behavior. For example, the laundry treatment machine is a washing machine or a drying machine or a combined washing and drying machine.

[0002] The estimation of a load inertia at the beginning of a washing cycle has a key role to set the amount of resources such as water, detergent, bleach and softener and the amount of energy in order to achieve a good washing performance without wasting resources and energy. The load inertia is caused by the laundry within the drum of the laundry treatment machine and varies in a wide range.

[0003] The washing unit is suspended to the cabinet by a set of springs and dampers. This mechanical system is adjusted to have a resonance frequency at a relatively low angular speed between 150 rpm and 300 rpm. During the spinning phase, the angular speed of the drum has to cross this resonance region without interference between the tub and the cabinet. Due to an increase of the drum size and a loading capacity of the laundry treatment machine the available space between the tub and the cabinet decreased. As a consequence, a precise estimation of a load unbalance is required in order to avoid a mechanical impact between the tub and the cabinet when the resonance region is crossed.

[0004] US 2005/204482 A1 discloses a method to estimate a load inertia and a load unbalance. The estimation is based on an angular speed signal and a torque signal during an acceleration of the drum or during superimposition of a dither signal to a substantially constant angular speed in order to excite the mechanical system of the laundry treatment machine.

[0005] EP 2 607 535 A2 discloses a method of operating a laundry treating appliance comprising at least one cycle of operation controlling the extraction of liquid from the laundry load on the basis of the inertia of the laundry load. US 2019/0112745 A1 discloses a method of operating a laundry washing machine.

[0006] It is an object of the present invention to provide a method to estimate a load behavior in a laundry treatment machine in an easy, reliable and accurate manner.

[0007] This object is achieved by a method comprising the steps of claim 1. According to the inventive method the inertia and the load torque is determined based on two operations of the laundry treatment machine with two different speed controller parameters and bandwidths of the speed controller. The speed controller regulates the angular speed of the drive motor and is part of the speed control loop. The first operation can be described by

$$-\hat{T}_L + T_{em}^{*1} = \hat{J}_t \hat{\omega}^1 \quad (1)$$

and the second operation can be described by

$$-\hat{T}_L + T_{em}^{*2} = \hat{J}_t \hat{\omega}^2 \quad (2),$$

wherein T_{em}^{*1} denotes the first torque signal,

$\hat{\omega}^1$ denotes the derivative of the first angular speed signal,

T_{em}^{*2} denotes the second torque signal,

$\hat{\omega}^2$ denotes the derivative of the second angular speed signal,

$\hat{T}_L$ denotes the load torque and

$\hat{J}_t$ denotes the total inertia of the laundry treatment machine with regard to a rotation around the rotational axis.

[0008] Based on equations (1) and (2) the total inertia can be evaluated by

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\hat{\omega}^1 - \hat{\omega}^2} \quad (3).$$

[0009] The load inertia can be evaluated by

$$\hat{J}_L = \hat{J}_t - J_m \quad (4),$$

wherein

$\hat{J}_L$ denotes the load inertia and

J_m denotes the inertia of the laundry treatment machine.

[0010] The inertia J_m of the laundry treatment machine is known from construction data or can be measured by running a test without a distributed load inside the drum.

[0011] Furthermore, in case that the load inertia is evaluated according to equation (4), the load torque can be determined, for example according to equation (1) and/or equation (2) and/or by means of a load observer as soon as the total inertia $\hat{J}_t$ is estimated according to equation (3) and the load torque observer is parametrized accordingly.

[0012] The load torque observer enables an accurate and continuous estimation of the load torque. The load torque observer can be easily implemented into a control unit of a laundry treatment machine. Additional hardware components, like sensors, are not required.

[0013] The advantages of the inventive method are as follows:

The load inertia and the total inertia can be evaluated at a constant angular speed, for example at 100 rpm, in order to avoid the use of an acceleration ramp and to avoid the risk of a mechanical impact between the tub and the cabinet. The same applies for the estimation of a load unbalance based on the load torque. The method can be used to estimate the dry load at the beginning of the washing cycle without using an acceleration ramp in order to set the amount of resources and energy. In case of a combined washing and drying machine or a drying machine the inertia estimation can be used to stop the drying cycle at a desired moisture retention. Furthermore, the inventive method can be used to estimate the wet load at the end of the washing cycle without using an acceleration ramp. The estimated load torque and an estimation of the load unbalance based thereon can be automatically adapted with the estimated total inertia. The inventive method can be used in a laundry treatment machine with a large drum and can be easily implemented in existing control units. The estimation of the inertia and/or the load torque is not affected by friction or by the speed controller setting. Furthermore, the estimation of the inertia and/or the load torque just requires an operation of the laundry treatment machine at a constant angular speed without the need of an acceleration ramp such that the inertia and/or the load torque can be estimated in an easy and quick manner.

[0014] A method according to claim 2 ensures an easy, reliable and accurate estimation of the load behavior. The desired angular speed or the target speed is constant. The resulting speed fluctuations or speed oscillations depend on the bandwidth of the speed controller and/or on the controller parameters of the speed controller, on the mass of the load and on the total inertia. A change of the speed controller parameters that changes the bandwidth of the speed controller at a constant desired angular speed results in a change of the speed oscillations and of the drive torque. The angular speed oscillations about the constant desired angular speed could be, as example, within ± 10 rpm, or within ± 5 rpm, or within ± 2 rpm.

[0015] A method according to claim 3 ensures an easy, reliable and accurate estimation of the load behavior. The mass of the load can be estimated in an easy and accurate manner depending on the load torque. The unbalance mass can be estimated by

$$\hat{m} = \frac{\max(\hat{T}_L)}{g \cdot r} \quad (5),$$

wherein

$\hat{m}$ denotes the mass of the load which corresponds to the unbalance mass,
 $\max(\hat{T}_L)$ denotes the maximum of the load torque,
 g denotes the gravitational acceleration and
 r denotes the drum radius.

[0016] A method according to claim 4 ensures an easy, reliable and accurate estimation of the load behavior. The angular load position can be estimated by solving

$$\hat{T}_L = -\hat{m} g r \sin(\hat{\theta} + \hat{\sigma}) \quad (6),$$

wherein

$\hat{\theta}$ denotes the angular drum position in relation to a reference position,
 $\hat{\sigma}$ denotes the angular relative load position inside the drum,
 $\hat{T}_L$ denotes the load torque,
 $\hat{m}$ denotes the mass of the load which corresponds to the unbalance mass,
 g denotes the gravitational acceleration and
 r denotes the drum radius.

[0017] The angular load position can be described by

$$\hat{\alpha} = \hat{\theta} + \hat{\sigma},$$

wherein

$\hat{\alpha}$ denotes the angular position of the load in relation to the reference position such that

$$\hat{T}_L = -\hat{m} g r \cos(\hat{\alpha})$$

since the load torque has a maximum value, if $\hat{\alpha} = 90^\circ$.

[0018] A method according to claim 5 ensures an easy, reliable and accurate estimation of the load behavior. The total inertia can be easily estimated according to equation (3). Furthermore, the load inertia can be easily estimated according to equation (4).

[0019] A method according to claim 6 ensures an easy, reliable and accurate estimation of the load behavior. The signals are transformed into a frequency domain, in particular by computing a Fourier Transformation (FT). This transformation enables to determine respective first harmonics of the signals. The first harmonics are used for the subsequent determination of the inertia and/or the load torque. The determination of the inertia and/or the load torque is not affected by noise signals. The first harmonics comprise information about the frequency, the amplitude and the phase of the signals. At least one of the frequency, the amplitude and the phase are used for the subsequent estimation of the inertia and/or the load torque.

[0020] A method according to claim 7 ensures an easy, reliable and accurate estimation of the load behavior. By using the first harmonics of the signals the estimation of the inertia and/or the load torque is not affected by noise signals. The first harmonics of the signals are calculated for example by a Fourier Transformation (FT). The first harmonics comprise information about the frequency, the amplitude and the phase of the signals. At least one of the frequency, the amplitude and the phase are used for the subsequent estimation of the inertia and/or the load torque.

[0021] A method according to claim 8 ensures an easy, reliable and accurate estimation of the load behavior. The angular position and/or the drive torque of the drive motor can either be measured or estimated. The angular position is used to calculate an observer error.

[0022] A method according to claim 9 ensures an easy, reliable and accurate estimation of the load behavior. The observer error is used to estimate and/or correct internal states of the load torque observer. The internal states of the load torque observer are in particular the observed angular position, an observed angular acceleration and the load torque. The observer error is multiplied with observer coefficients or observer gains. The observer coefficients are used to adapt the accuracy and the behavior of the load torque observer.

[0023] A method according to claim 10 ensures an easy, reliable and accurate estimation of the load behavior. The observer error is multiplied with observer coefficients or observer gains in order to calculate observer signals. These observer signals are used to estimate and/or correct the internal states of the observer. A first observer signal is calculated by multiplying a derivative of the observer error with a first observer coefficient. A second observer signal is calculated by multiplying the observer error with a second observer coefficient. Furthermore, a third observer signal is calculated by multiplying the observer error with a third observer coefficient and by integrating the resulting signal. The load torque depends on the sum of the first observer signal, the second observer signal and the third observer signal.

[0024] A method according to claim 11 ensures an easy, reliable and accurate estimation of the load behavior. An observed angular acceleration and in consequence the observed angular position depends on the total inertia of the laundry treatment machine and the load. The total inertia is estimated according to equation (3). The total inertia can be adapted during the operation of the laundry treatment machine, if necessary. For example, the total inertia increases depending on the wetness of the laundry.

[0025] A method according to claim 12 ensures an easy, reliable and accurate estimation of the load behavior. Sensorless drive motors are well known and do not comprise an angular position sensor and an angular speed sensor. Hence, the angular position of the drive motor is estimated, for example by means of a position and/or speed estimator or a position and/or speed observer. The load torque observer is preferably provided with an estimated angular position of the drive motor.

[0026] A method according to claim 13 ensures an easy, reliable and accurate estimation of the load behavior. The load torque observer is provided with the desired drive torque of the drive motor. An output signal of the speed controller is used to estimate the drive torque. This output signal characterizes the desired electromagnetic drive torque of the drive motor and can be used to estimate the drive torque and/or the load torque which acts on the drum.

[0027] Furthermore, it is an object of the present invention to provide a laundry treatment machine which enables to estimate a load behavior in an easy, reliable and accurate manner.

[0028] This object is achieved by a laundry treatment machine with the features of claim 14. The advantages of the laundry treatment machine according to the invention correspond to the advantages already described in connection with the method according to the invention.

[0029] Further features, advantages and details of the invention will be apparent from the following description of an embodiment which refers to the accompanying drawings.

Fig. 1 shows a schematic view of a laundry treatment machine with a drum, a drive motor and a control unit,

Fig. 2 shows a schematic cross sectional view of the drum with a load located inside the drum,

Fig. 3 shows a block diagram of a controller and a load torque observer implemented in the control unit,

Fig. 4 shows a block diagram of the load torque observer in Fig. 3,

Fig. 5 shows a flow chart of a method to estimate a total inertia of the laundry treatment machine and the load with respect to a rotation of the drum around a rotational axis,

Fig. 6 shows a time diagram of an angular speed and a drive torque of the drive motor during a first operation and a second operation of the laundry treatment machine in order to estimate the total inertia according to the flow chart in Fig. 5,

Fig. 7 shows a first torque signal and a first angular acceleration signal during a first operation and a second torque signal and a second angular acceleration signal during a second operation of the laundry treatment machine as well as a torque difference signal and an acceleration difference signal depending on the angular position of the drum in order to estimate the total inertia, and

Fig. 8 shows an estimated load torque depending on an angular position of the drum.

[0030] Fig. 1 shows a laundry treatment machine, namely a washing machine 1 with a cabinet 2 and a washing unit 3. The washing unit 3 comprises a tub 4 and a drum 5. The tub 4 is mounted to the cabinet 2 via dampers 6 and springs 7.

[0031] The drum 5 is mounted in a rotatable manner to the tub 4. The drum 5 is connected via a drive shaft 8 with a drive motor 9. The drive motor 9 is mounted at a backside of the tub 4. The drive motor 9 rotates the drum 5 around a horizontal rotational axis 10.

[0032] The washing machine 1 comprises several lifters 11 to move the laundry. The lifters 11 are mounted in equal angular distances to an inner side of the drum 5.

[0033] Furthermore, the washing machine 1 comprises a control unit 12 to control the operation of the washing machine 1. The drive motor 9 has an angular position Θ , an angular speed ω and an angular acceleration $\dot{\omega}$. Due to the stiff drive shaft 8 the angular position, the angular speed and the angular acceleration of the drum 5 corresponds to the angular position Θ , the angular speed ω and the angular acceleration $\dot{\omega}$. In case of belt driven motor, the pulley ratio will be used to evaluate the angular position, the angular speed and the angular acceleration of the drum starting from the angular position, the angular speed and the angular acceleration of the motor.

[0034] The load L, namely the laundry inside the drum 5 produces a load torque T_L . In case that the angular speed of the drum 5 is higher than a saturation speed the load torque T_L can be described by

$$T_L = -mgr \sin(\theta + \sigma) \quad (7),$$

wherein

m denotes the real mass of the load L,

g denotes the gravitational acceleration,

r denotes the drum radius,

Θ denotes the angular position of the drum in relation to a reference position Θ_0 , and

σ denotes the angular relative position of the load L inside the drum, namely an angle between the position of the load L and a drum reference position.

[0035] The angular position α of the load L can be described by

$$\alpha = \theta + \sigma \quad (8),$$

wherein

α denotes the angular position of the load L in relation to the reference position θ_0 .

[0036] The angular positions σ and α and the mass m are unknown. The gravitational acceleration g and the drum radius r are known. The load torque T_L has a maximum value if $\alpha = 90^\circ$ such that

$$T_L = -mgr \cos(\alpha).$$

[0037] The drive motor 9 creates a drive torque T_{em} which accelerates the drum 5.

[0038] The drive torque T_{em} is superimposed by the load torque T_L .

[0039] The control unit 12 comprises a speed controller 13, a torque controller 14, a first coordinate transformation 15, a pulse width modulator 16, a position and speed observer 17, a second coordinate transformation 18 and a load torque observer 19.

[0040] The torque controller 14 is part of an inner control loop or a torque control loop to control the drive torque T_{em} of the drive motor 9. For example, the torque controller 14 is a PI controller. The torque controller 14 is provided with a desired

drive torque T_{em}^* and the drive motor currents which are denoted in common with i_{abc} . The drive motor currents i_{abc} are transformed by means of the second coordinate transformation 18 into a dq coordinate system. The corresponding currents are denoted in common with i_{dq} . The torque controller 14 creates in the dq coordinate system desired voltages which are denoted in common with v_{dq}^* . The voltages v_{dq}^* are transformed by means of the first coordinate transformation 15 into desired voltages in an abc coordinate system which are denoted in common with v_{abc} . The voltages v_{abc} are provided to the pulse width modulator 16 which creates via a switch circuit currents i_a, i_b, i_c to operate the drive motor 9 with a torque T_{em} which corresponds to the desired torque T_{em}^* .

[0041] The drive motor 9 is designed sensorless, namely without a speed sensor and a torque sensor. Therefore, the position and speed observer 17 is used to produce an estimated angular position $\hat{\theta}$ and an estimated angular speed $\hat{\omega}$. The position and speed observer 17 is provided with the voltages v_{abc} and the currents i_{abc} . The estimated angular position $\hat{\theta}$ is provided to the first coordinate transformation 15 and the second coordinate transformation 18.

[0042] The speed controller 13 is part of an outer control loop or a speed control loop. The speed controller 13 is provided with the difference of a desired angular speed ω^* and the estimated angular speed $\hat{\omega}$. The output signal of the speed

controller 13 is the desired drive torque T_{em}^* .

[0043] The load torque observer 19 evaluates an estimated load torque $\hat{T}_L$. The load torque observer 19 is provided with the desired drive torque T_{em}^* and the estimated angular position $\hat{\theta}$ as input signals. The load torque observer 19 calculates an observer error e_{obs} which is the difference of the estimated angular position $\hat{\theta}$ and an observed angular position θ_{obs} .

[0044] The load torque observer 19 calculates three observer signals k_1, k_2 and k_3 . These observer signals can be described by:

$$k_1 = K1 \cdot s \cdot e_{obs} \quad (9),$$

$$k_2 = K2 \cdot e_{obs} \quad (10),$$

$$k_3 = K3/s \cdot e_{obs} \quad (11),$$

wherein

k_1 denotes a first observer coefficient,
 k_2 denotes a second observer coefficient,
 k_3 denotes a third observer coefficient,
 s denotes a derivator, and
 $1/s$ denotes an integrator.

[0045] The observer coefficients are for example set to

$$K1 = 64,$$

$$K2 = 13,$$

and

$$K3 = 5.$$

[0046] The estimated load torque T_L can be calculated by

$$\hat{T}_L = -(k_1 + k_2 + k_3) \quad (12).$$

[0047] The load torque observer 19 calculates an observed angular acceleration $\dot{\omega}_{obs}$ by

$$\dot{\omega}_{obs} = \frac{1}{\hat{J}_t} \cdot (T_{em}^* - \hat{T}_L) \quad (13),$$

wherein

$\hat{J}_t$ is the total inertia of those parts of the washing machine 1 which rotate around the rotational axis 10, in particular of the drum 5 with the balancers 11, of the drive shaft 8, of the drive motor 9, and of the load L. The total inertia can be described by

$$\hat{J}_t = \hat{J}_L + J_m \quad (14),$$

wherein

$\hat{J}_L$ denotes the load inertia and J_m denotes the inertia of the washing machine 1. The inertia of the washing machine 1 is known from construction data.

[0048] The load torque observer 19 calculates an observed angular speed ω_{obs} by integrating the observed angular acceleration $\dot{\omega}_{obs}$. Furthermore, the load torque observer 19 calculates the observed angular position θ_{obs} by integrating the observed angular speed ω_{obs} .

[0049] In the following the estimation of the total inertia $\hat{J}_t$ is described in detail:

In step S_1 the speed controller 13 is parametrized with first controller parameters P_1 . For example, the speed controller 13 is a PI controller.

[0050] In a second step S_2 the drum 5 is accelerated by means of the drive motor 9 as example from 0 rpm to 100 rpm.

[0051] Afterwards, in a third step S_3 the drum 5 is rotated with an essentially constant drum speed ω . During the third step

S_3 the control unit 12 transforms the desired drive torque T_{em}^* and the estimated angular speed $\hat{\omega}$ into the frequency

domain by calculating a Fourier Transformation. The first harmonic of the desired drive torque T_{em}^* is stored in the control

unit 12 and is denoted T_{em}^{*1} . Furthermore, the first harmonic information, for example the frequency, the amplitude and

the phase, of the estimated angular speed $\hat{\omega}$ are used to get an estimated angular acceleration which is denoted $\widehat{\dot{\omega}}^1$. The

estimated angular acceleration $\widehat{\dot{\omega}}^1$ is stored in the control unit 12.

[0052] Afterwards, in a step S_4 the speed controller 13 is parametrized with second controller parameters P_2 .

[0053] Afterwards, in a fifth step S_5 the drum 5 is rotated with an essentially constant drum speed ω . During the step S_5

the control unit 12 transforms the desired drive torque T_{em}^* and the estimated angular speed $\hat{\omega}$ into the frequency domain

by calculating a Fourier Transformation. The first harmonic of the desired drive torque T_{em}^* is stored in the control unit 12

and is denoted T_{em}^{*2} . Furthermore, the first harmonic information, for example the frequency, the amplitude and the

phase, of the estimated angular speed $\hat{\omega}$ are used to get an estimated angular acceleration which is denoted $\widehat{\dot{\omega}}^2$. The

estimated angular acceleration $\widehat{\dot{\omega}}^2$ is stored in the control unit 12.

[0054] In a subsequent sixth step S6 the total inertia can be calculated by

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\widehat{\dot{\omega}}^1 - \widehat{\dot{\omega}}^2} \quad (15).$$

[0055] The estimated total inertia $\hat{J}_t$ is used to parametrize the load torque observer 19. Equation (15) is illustrated in fig. 7.

[0056] After parameterization the load torque observer 19 can be used in a seventh step to observe and estimate the load torque $\hat{T}_L$. Furthermore, the load inertia can be calculated by

$$\hat{J}_L = \hat{J}_t - J_m \quad (16),$$

and the estimated mass $\hat{m}$ of the load or the unbalance mass can be calculated by

$$\hat{m} = \frac{\max(\hat{T}_L)}{gr} \quad (17).$$

[0057] The angular position $\hat{\theta}$ of the load L is already known. Fig. 8 illustrates the estimated load torque $\hat{T}_L$.

[0058] The load inertia $\hat{J}_L$, the load torque $\hat{T}_L$, the mass $\hat{m}$ and the angular load position $\hat{\theta}$ characterize the behavior of the load L and can be used for several purposes, for example to adapt the maximum spinning speed, to compensate the load L by filling the balancers 11 with water, to estimate the dry load at the beginning of the washing cycle and to set properly the required amount of water and/or detergent, to estimate the wet load at the beginning of the spinning cycle and to estimate the remaining moisture retention during a drying process.

Claims

1. Method to estimate a load behavior in a laundry treatment machine with the steps of:

- providing a laundry treatment machine (1) with a drum (5), a drive motor (9) to rotate the drum (5) around a rotational axis (10) and a controller (13) to regulate an angular speed of the drive motor (9),
- performing a first operation of the laundry treatment machine (1) with a load (L) inside the drum (5), wherein the controller (13) is operated with first controller parameters (P_1),
- determining a first torque signal T_{em}^{*1} and a derivative $\widehat{\dot{\omega}}^1$ of a first angular speed signal of the drive motor (9) based on the first operation,
- performing a second operation of the laundry treatment machine (1) with the load (L) inside the drum (5), wherein the controller (13) is operated with second controller parameters (P_2),
- determining a second torque signal T_{em}^{*2} and a derivative $\widehat{\dot{\omega}}^2$ of a second angular speed signal of the drive motor (9) based on the second operation, and
- determining an inertia $\hat{J}_t$ with the equation

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\widehat{\dot{\omega}}^1 - \widehat{\dot{\omega}}^2}$$

and characterized by:

determining a load torque ($\hat{T}_L$) caused by the load (L) depending on the first torque signal T_{em}^{*1} , the second torque signal T_{em}^{*2} , the derivative $\widehat{\dot{\omega}}^1$ of the first angular speed signal and the derivative $\widehat{\dot{\omega}}^2$ of the second angular speed signal, wherein the load torque ($\hat{T}_L$) is determined by means of a load torque observer (19).

2. Method according to claim 1, characterized in

that at least one of the first operation and the second operation is performed at a constant desired target angular speed (ω^*), while in particular a real speed (ω) oscillates according to the controller parameters (P_1 , P_2) and the load (L).

3. Method according to claim 1 or 2, characterized

by the step of determining a mass ($\hat{m}$) of the load (L) depending on the load torque ($\hat{T}_L$).

4. Method according to at least one of the preceding claims, characterized

by the step of determining an angular load position ($\hat{\alpha}$) of the load (L) depending on the load torque ($\hat{T}_L$).

5. Method according to at least one of the preceding claims, characterized

by the step of determining a total inertia (J_t) of the laundry treatment machine (1) and the load (L), wherein in particular a load inertia (J_L) is the difference between the total inertia (J_t) and a machine inertia (J_m).

6. Method according to at least one of the preceding claims, characterized in

that the first torque signal (T_{em}^{*1}), the second torque signal (T_{em}^{*2}), the first angular speed signal and the second angular speed signal are transformed into a frequency domain.

7. Method according to at least one of the preceding claims, characterized in

that a respective first harmonic of the first torque signal (T_{em}^{*1}), of the second torque signal (T_{em}^{*2}), of the first angular speed signal and of the second angular speed signal are used to determine the inertia ($\hat{J}_t$, $\hat{J}_L$) and/or the load torque ($\hat{T}_L$).

8. Method according to at least one of the preceding claims, characterized in

that the load torque observer (19) is provided with an angular position ($\hat{\theta}$) of the drive motor (9) and/or a drive torque (T_{em}^*) of the drive motor (9).

9. Method according to at least one of the preceding claims, characterized in

that the load torque observer (19) determines an observer error (e_{obs}) depending on an angular position ($\hat{\theta}$) of the drive motor (9) and an observed angular position (θ_{obs}).

10. Method according to at least one of the preceding claims, characterized in

that the load torque observer (19) determines observer signals (k_1 , k_2 , k_3) depending on an observer error (e_{obs}) and observer coefficients (K_1 , K_2 , K_3) to determine the load torque ($\hat{T}_L$) and/or an observed angular position (θ_{obs}).

11. Method according to at least one of the preceding claims, characterized in

that the load torque observer (19) determines an observed angular position (θ_{obs}) depending on a total inertia (J_t) of the laundry treatment machine (1) and the load (L).

12. Method according to at least one of claims 8 to 11, characterized in that the drive motor (9) is designed sensorless and the angular position ($\hat{\theta}$) of the drive motor (9) is estimated, in particular by means of a position observer (17).

13. Method according to at least one of claims 8, characterized in that the drive torque (T_{em}^*) of the drive motor (9) is estimated or is the desired drive torque (T_{em}^*) and the output of the controller (13).

14. Laundry treatment machine with

- a drum (5),
- a drive motor (9) to rotate the drum (5) around a rotational axis (10), and
- a control unit (12) configured to estimate a load behavior with a controller (13) to regulate an angular speed of the drive motor (9), wherein the control unit (12) is designed such that

-- a first operation of the laundry treatment machine (1) with a load (L) inside the drum (5) is performed, wherein the controller (13) is operated with first controller parameters (P_1),

-- a first torque signal T_{em}^{*1} and a derivative $\widehat{\dot{\omega}}^1$ of a first angular speed signal of the drive motor (9) are

determined based on the first operation,

-- a second operation of the laundry treatment machine (1) with the load (L) inside the drum (5) is performed, wherein the controller (13) is operated with second controller parameters (P_2),

-- a second torque signal T_{em}^{*2} and a derivative $\hat{\omega}^2$ of a second angular speed signal of the drive motor (9) are determined based on the second operation, and
 -- an inertia $\hat{J}_t$ using the equation

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\hat{\omega}^1 - \hat{\omega}^2}$$

and **characterized in that:**

a load torque ($\hat{T}_L$) caused by the load (L) is determined depending on the first torque signal T_{em}^{*1} , the second torque signal T_{em}^{*2} , the derivative $\hat{\omega}^1$ of the first angular speed signal and the derivative $\hat{\omega}^2$ of the second angular speed signal, wherein the load torque ($\hat{T}_L$) is determined by means of a load torque observer (19).

Patentansprüche

1. Verfahren zum Schätzen eines Lastverhaltens in einer Wäschebehandlungsmaschine mit den Schritten:

- Bereitstellen einer Wäschebehandlungsmaschine (1) mit einer Trommel (5), einem Antriebsmotor (9) zum Drehantreiben der Trommel (5) um eine Drehachse (10) und einer Steuerung (13) zum Regeln einer Winkelgeschwindigkeit des Antriebsmotors (9),
- Durchführen eines ersten Arbeitsganges der Wäschebehandlungsmaschine (1) mit einer Beladung (L) in der Trommel (5), wobei die Steuerung (13) mit ersten Steuerungsparametern (P_1) betrieben wird,
- Bestimmen eines ersten Drehmomentsignals T_{em}^{*1} und einer Ableitung $\hat{\omega}^1$ eines ersten Winkelgeschwindigkeitssignals des Antriebsmotors (9) auf der Grundlage des ersten Arbeitsganges,
- Durchführen eines zweiten Arbeitsganges der Wäschebehandlungsmaschine (1) mit der Beladung (L) in der Trommel (5), wobei die Steuerung (13) mit zweiten Steuerungsparametern (P_2) betrieben wird,
- Bestimmen eines zweiten Drehmomentsignals T_{em}^{*2} und einer Ableitung $\hat{\omega}^2$ eines zweiten Winkelgeschwindigkeitssignals des Antriebsmotors (9) auf der Grundlage des zweiten Arbeitsganges, und
- Bestimmen einer Trägheit $\hat{J}_t$ mit der Gleichung

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\hat{\omega}^1 - \hat{\omega}^2}$$

und **gekennzeichnet durch:**

Bestimmen eines Lastmoments ($\hat{T}_L$), welches von der Beladung (L) verursacht wird, in Abhängigkeit von dem ersten Drehmomentsignal T_{em}^{*1} , dem zweiten Drehmomentsignal T_{em}^{*2} , der Ableitung $\hat{\omega}^1$ des ersten Winkelgeschwindigkeitssignals und der Ableitung $\hat{\omega}^2$ des zweiten Winkelgeschwindigkeitssignals, wobei das Lastmoment ($\hat{T}_L$) mithilfe eines Lastmomentbeobachters (19) bestimmt wird.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,**

dass mindestens einer von dem ersten Arbeitsgang und dem zweiten Arbeitsgang bei einer konstanten Soll-Winkelgeschwindigkeit (ω^*) durchgeführt wird, während insbesondere eine reale Geschwindigkeit (ω) entsprechend den Steuerungsparametern (P_1 , P_2) und der Beladung (L) schwankt.

3. Verfahren nach der Ansprüche 1 oder 2, **gekennzeichnet durch** den Schritt des Bestimmens einer Masse ($\hat{m}$) der Beladung (L) in Abhängigkeit von dem Lastmoment ($\hat{T}_L$).

4. Verfahren nach mindestens einem der vorhergehenden Ansprüche, **gekennzeichnet**
durch den Schritt des Bestimmens einer Lastwinkelposition ($\hat{\alpha}$) der Beladung (L) in Abhängigkeit von dem Lastmoment ($\hat{T}_L$).
5. Verfahren nach mindestens einem der vorhergehenden Ansprüche, **gekennzeichnet**
durch den Schritt des Bestimmens einer Gesamtträgheit ($\hat{J}_t$) der Wäschebehandlungsmaschine (1) und der Beladung (L), wobei insbesondere eine Ladungsträgheit ($\hat{J}_L$) die Differenz zwischen der Gesamtträgheit ($\hat{J}_t$) und einer Maschinenträgheit (J_m) beträgt.
6. Verfahren nach mindestens einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
dass das erste Drehmomentsignal (T_{em}^{*1}), das zweite Drehmomentsignal (T_{em}^{*2}), das erste Winkelgeschwindigkeitssignal und das zweite Winkelgeschwindigkeitssignal in einen Frequenzbereich transformiert werden.
7. Verfahren nach mindestens einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
dass eine jeweilige erste Harmonische des ersten Drehmomentsignals (T_{em}^{*1}), des zweiten Drehmomentsignals (T_{em}^{*2}), des ersten Winkelgeschwindigkeitssignals und des zweiten Winkelgeschwindigkeitssignals zum Bestimmen der Trägheit ($\hat{J}_t$, $\hat{J}_L$) und/oder des Lastmoments ($\hat{T}_L$) verwendet werden.
8. Verfahren nach mindestens einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
dass der Lastmomentbeobachter (19) eine Winkelposition ($\hat{\theta}$) des Antriebsmotors (9) und/oder ein Antriebsmoment (T_{em}^*) des Antriebsmotors (9) erhält.
9. Verfahren nach mindestens einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
dass der Lastmomentbeobachter (19) einen Beobachterfehler (e_{obs}) in Abhängigkeit von einer Winkelposition ($\hat{\theta}$) des Antriebsmotors (9) und einer beobachteten Winkelposition (θ_{obs}) bestimmt.
10. Verfahren nach mindestens einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
dass der Lastmomentbeobachter (19) Beobachtersignale (k_1 , k_2 , k_3) in Abhängigkeit von einem Beobachterfehler (e_{obs}) und Beobachterkoeffizienten (K_1 , K_2 , K_3) zum Bestimmen des Lastmoments ($\hat{T}_L$) und/oder einer beobachteten Winkelposition (θ_{obs}) bestimmt.
11. Verfahren nach mindestens einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
dass der Lastmomentbeobachter (19) eine beobachtete Winkelposition (θ_{obs}) in Abhängigkeit von einer Gesamtträgheit ($\hat{J}_t$) der Wäschebehandlungsmaschine (1) und der Beladung (L) bestimmt.
12. Verfahren nach mindestens einem der Ansprüche 8 bis 11, **dadurch gekennzeichnet, dass** der Antriebsmotor (9) sensorlos ausgeführt ist und die Winkelposition ($\hat{\theta}$) des Antriebsmotors (9) geschätzt wird, insbesondere mithilfe eines Positionsbeobachters (17).
13. Verfahren nach mindestens einem der Ansprüche 8, **dadurch gekennzeichnet,**
dass das Antriebsmoment (T_{em}^*) des Antriebsmotors (9) geschätzt wird oder das gewünschte Antriebsmoment (T_{em}^*) und die Ausgabe der Steuerung (13) beträgt.
14. Wäschebehandlungsmaschine mit
 - einer Trommel (5),
 - einem Antriebsmotor (9) zum Drehantreiben der Trommel (5) um eine Drehachse (10), und
 - einer Steuereinheit (12), welche dazu ausgebildet ist, mit einer Steuerung (13) ein Lastverhalten abzuschätzen,

um eine Winkelgeschwindigkeit des Antriebsmotors (9) zu steuern, wobei die Steuereinheit (12) so ausgebildet ist, dass

- ein erster Arbeitsgang der Wäschebehandlungsmaschine (1) mit einer Beladung (L) in der Trommel (5) durchgeführt wird, wobei die Steuerung (13) mit ersten Steuerungsparametern (P_1) betrieben wird,
- ein erstes Drehmomentsignal T_{em}^{*1} und eine Ableitung $\widehat{\dot{\omega}}^1$ eines ersten Winkelgeschwindigkeitssignals des Antriebsmotors (9) auf der Grundlage des ersten Arbeitsgangs bestimmt werden,
- ein zweiter Arbeitsgang der Wäschebehandlungsmaschine (1) mit der Beladung (L) in der Trommel (5) durchgeführt wird, wobei die Steuerung (13) mit zweiten Steuerungsparametern (P_2) betrieben wird,
- ein zweites Drehmomentsignal T_{em}^{*2} und eine Ableitung $\widehat{\dot{\omega}}^2$ eines zweiten Winkelgeschwindigkeitssignals des Antriebsmotors (9) auf der Grundlage des zweiten Arbeitsganges bestimmt werden, und
- eine Trägheit $\hat{J}_t$ unter Verwendung der Gleichung

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\widehat{\dot{\omega}}^1 - \widehat{\dot{\omega}}^2}$$

und

dadurch gekennzeichnet, dass:

ein Lastmoment ($\hat{T}_L$), welches von der Beladung (L) verursacht wird, in Abhängigkeit von dem ersten Drehmomentsignal T_{em}^{*1} , dem zweiten Drehmomentsignal T_{em}^{*2} , der Ableitung $\widehat{\dot{\omega}}^1$ des ersten Winkelgeschwindigkeitssignals und der Ableitung $\widehat{\dot{\omega}}^2$ des zweiten Winkelgeschwindigkeitssignals bestimmt wird, wobei das Lastmoment ($\hat{T}_L$) mithilfe eines Lastmomentbeobachters (19) bestimmt wird.

Revendications

1. Procédé pour estimer le comportement d'une charge dans une machine de traitement de linge avec les étapes suivantes :

- mise à disposition d'une machine de traitement du linge (1) avec un tambour (5), un moteur d'entraînement (9) pour faire tourner le tambour (5) autour d'un axe de rotation (10) et un contrôleur (13) pour réguler une vitesse angulaire du moteur d'entraînement (9),
- mise en œuvre d'une première opération de la machine de traitement de linge (1) avec une charge (L) à l'intérieur du tambour (5), le contrôleur (13) étant actionné avec des premiers paramètres de contrôleur (P_1),
- détermination d'un premier signal de couple T_{em}^{*1} et d'une dérivée $\widehat{\dot{\omega}}^1$ d'un premier signal de vitesse angulaire du moteur d'entraînement (9) sur la base de la première opération,
- mise en œuvre d'une deuxième opération de la machine de traitement de linge (1) avec la charge (L) à l'intérieur du tambour (5), le contrôleur (13) étant actionné avec des deuxièmes paramètres de contrôleur (P_2),
- détermination d'un deuxième signal de couple T_{em}^{*2} et d'une dérivée $\widehat{\dot{\omega}}^2$ d'un deuxième signal de vitesse angulaire du moteur d'entraînement (9) sur la base de la deuxième opération, et
- détermination d'une inertie $\hat{J}_t$ avec l'équation

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\widehat{\dot{\omega}}^1 - \widehat{\dot{\omega}}^2}$$

et caractérisé par :

la détermination d'un couple de charge ($\hat{T}_L$) provoqué par la charge (L) en fonction du premier signal de couple T_{em}^{*1} , du deuxième signal de couple T_{em}^{*2} , de la dérivée $\widehat{\dot{\omega}}^1$ du premier signal de vitesse angulaire et de la dérivée $\widehat{\dot{\omega}}^2$ du deuxième signal de vitesse angulaire, le couple de charge ($\hat{T}_L$) étant déterminé au moyen d'un

observateur de couple de charge (19).

2. Procédé selon la revendication 1, **caractérisé en ce**
que la première opération et/ou la deuxième opération sont effectuées à une vitesse angulaire cible désirée constante (ω^*), tandis que, en particulier, une vitesse réelle (ω) oscille en fonction des paramètres du contrôleur (P_1, P_2) et de la charge (L).
3. Procédé selon la revendication 1 ou 2, **caractérisé**
par l'étape de détermination d'une masse ($\hat{m}$) de la charge (L) en fonction du couple de charge ($\hat{T}_L$).
4. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé**
par l'étape de détermination d'une position angulaire de charge ($\hat{\alpha}$) de la charge (L) en fonction du couple de charge ($\hat{T}_L$).
5. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé**
par l'étape de détermination d'une inertie totale ($\hat{J}_t$) de la machine de traitement de linge (1) et de la charge (L), dans laquelle en particulier une inertie de charge ($\hat{J}_L$) est la différence entre l'inertie totale ($\hat{J}_t$) et l'inertie de la machine (J_m).
6. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé en ce**
que le premier signal de couple (T_{em}^{*1}), le deuxième signal de couple (T_{em}^{*2}), le premier signal de vitesse angulaire et le deuxième signal de vitesse angulaire sont transformés dans un domaine de fréquence.
7. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé en ce**
qu'une première harmonique respective du premier signal de couple (T_{em}^{*1}), du deuxième signal de couple (T_{em}^{*2}), du premier signal de vitesse angulaire et du deuxième signal de vitesse angulaire sont utilisées pour déterminer l'inertie ($\hat{J}_t, \hat{J}_L$) et/ou le couple de charge ($\hat{T}_L$).
8. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé en ce**
que l'observateur de couple de charge (19) reçoit une position angulaire ($\hat{\theta}$) du moteur d'entraînement (9) et/ou un couple d'entraînement (T_{em}^*) du moteur d'entraînement (9).
9. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé en ce**
que l'observateur de couple de charge (19) détermine une erreur d'observateur (e_{obs}) en fonction d'une position angulaire ($\hat{\theta}$) du moteur d'entraînement (9) et d'une position angulaire observée (θ_{obs}).
10. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé en ce**
que l'observateur de couple de charge (19) détermine des signaux d'observateur (k_1, k_2, k_3) en fonction d'une erreur d'observateur (e_{obs}) et des coefficients d'observateur ($K1, K2, K3$) pour déterminer le couple de charge ($\hat{T}_L$) et/ou une position angulaire observée (θ_{obs}).
11. Procédé selon au moins l'une quelconque des revendications précédentes, **caractérisé en ce**
que l'observateur de couple de charge (19) détermine une position angulaire observée (θ_{obs}) en fonction d'une inertie totale ($\hat{J}_t$) de la machine de traitement de linge (1) et de la charge (L).
12. Procédé selon au moins l'une quelconque des revendications 8 à 11, **caractérisé en ce**
que le moteur d'entraînement (9) est conçu sans capteur et que la position angulaire ($\hat{\theta}$) du moteur d'entraînement (9) est estimée, en particulier au moyen d'un observateur de position (17).
13. Procédé selon au moins l'une quelconque de la revendication 8, **caractérisé en ce**
que le couple d'entraînement (T_{em}^*) du moteur d'entraînement (9) est estimé ou est le couple d'entraînement souhaité (T_{em}^*) et la sortie du contrôleur (13).
14. Machine de traitement de linge avec

- un tambour (5),
- un moteur d'entraînement (9) pour faire tourner le tambour (5) autour d'un axe de rotation (10), et
- une unité de commande (12) configurée pour estimer un comportement de charge avec un contrôleur (13) pour réguler une vitesse angulaire du moteur d'entraînement (9), l'unité de commande (12) étant conçue de sorte que

-- une première opération de la machine de traitement de linge (1) avec une charge (L) à l'intérieur du tambour (5) est effectuée, le contrôleur (13) étant actionné avec des premiers paramètres de contrôleur (P_1),

-- un premier signal de couple T_{em}^{*1} et une dérivée $\widehat{\dot{\omega}}^1$ d'un premier signal de vitesse angulaire du moteur d'entraînement (9) sont déterminés sur la base de la première opération,

-- une deuxième opération de la machine de traitement de linge (1) avec la charge (L) à l'intérieur du tambour (5) est effectuée, le contrôleur (13) étant actionné avec des deuxième paramètres de contrôleur (P_2),

-- un deuxième signal de couple T_{em}^{*2} et une dérivée $\widehat{\dot{\omega}}^2$ d'un deuxième signal de vitesse angulaire du moteur d'entraînement (9) sont déterminés sur la base de la deuxième opération, et

-- une inertie $\hat{J}_t$ en utilisant l'équation

$$\hat{J}_t = \frac{T_{em}^{*1} - T_{em}^{*2}}{\widehat{\dot{\omega}}^1 - \widehat{\dot{\omega}}^2}$$

et

caractérisée en ce

que :

un couple de charge ($\hat{T}_L$) provoqué par la charge (L) est déterminé en fonction du premier signal de couple

T_{em}^{*1} , du deuxième signal de couple T_{em}^{*2} , de la dérivée $\widehat{\dot{\omega}}^1$ du premier signal de vitesse angulaire et de

la dérivée $\widehat{\dot{\omega}}^2$ du deuxième signal de vitesse angulaire, le couple de charge ($\hat{T}_L$) étant déterminé au moyen d'un observateur de couple de charge (19).

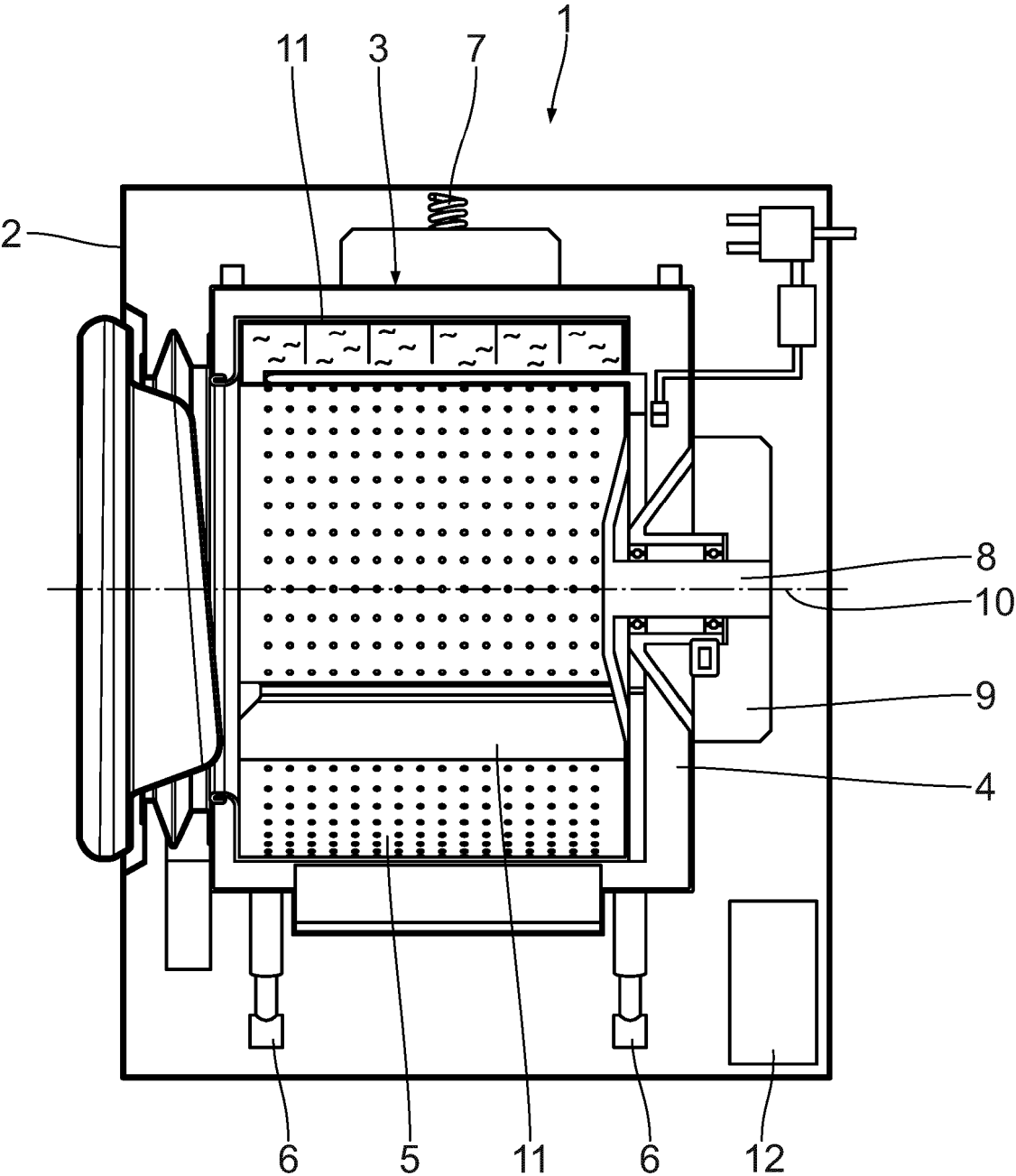


Fig. 1

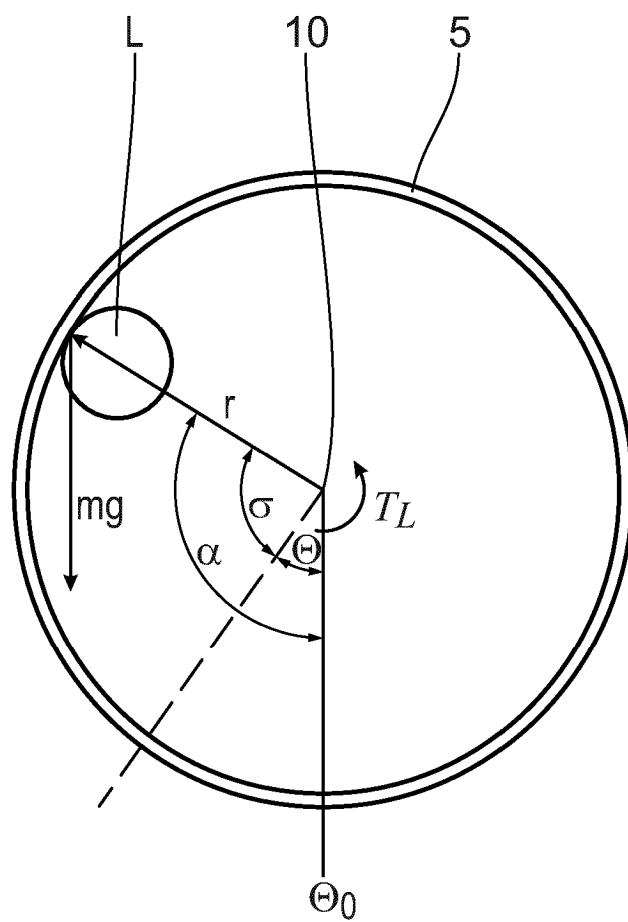


Fig. 2

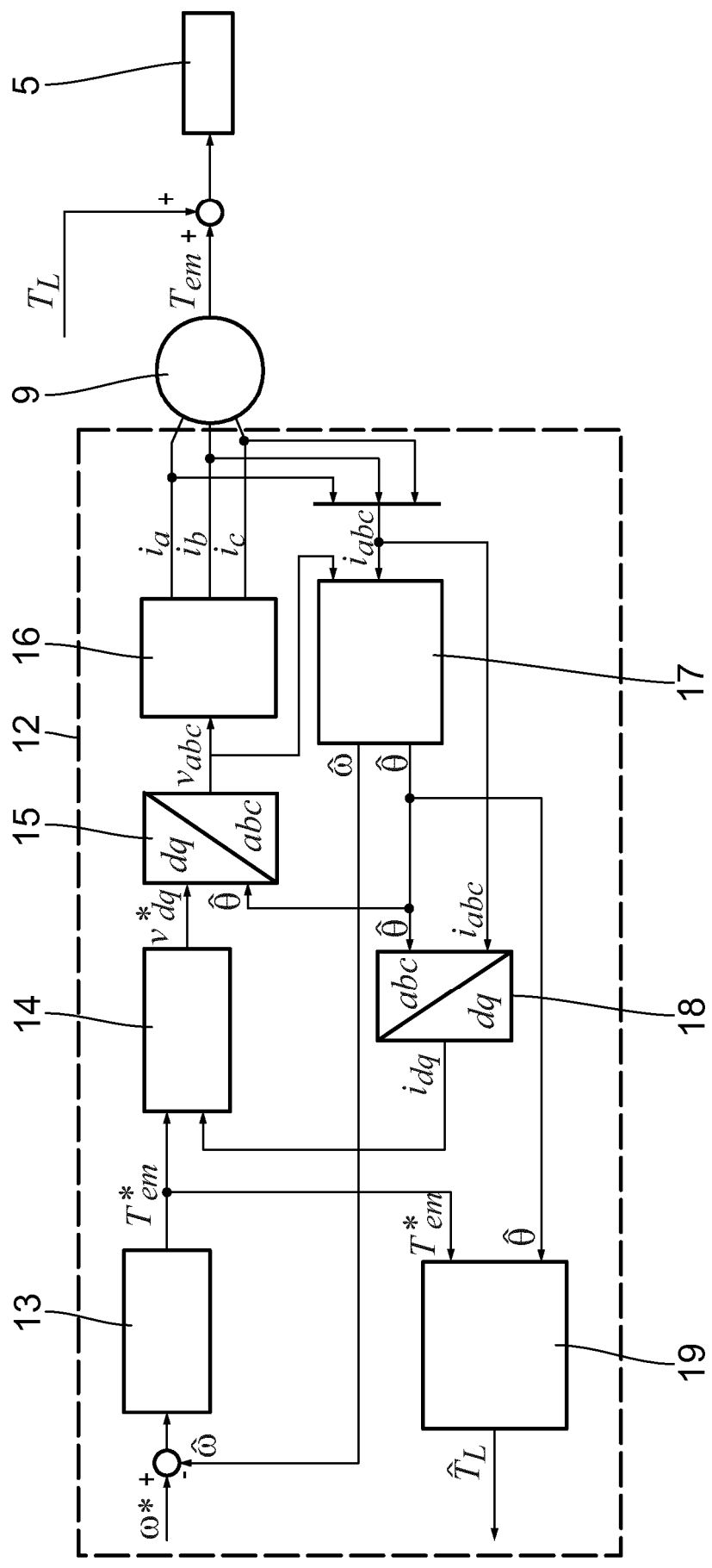


Fig. 3

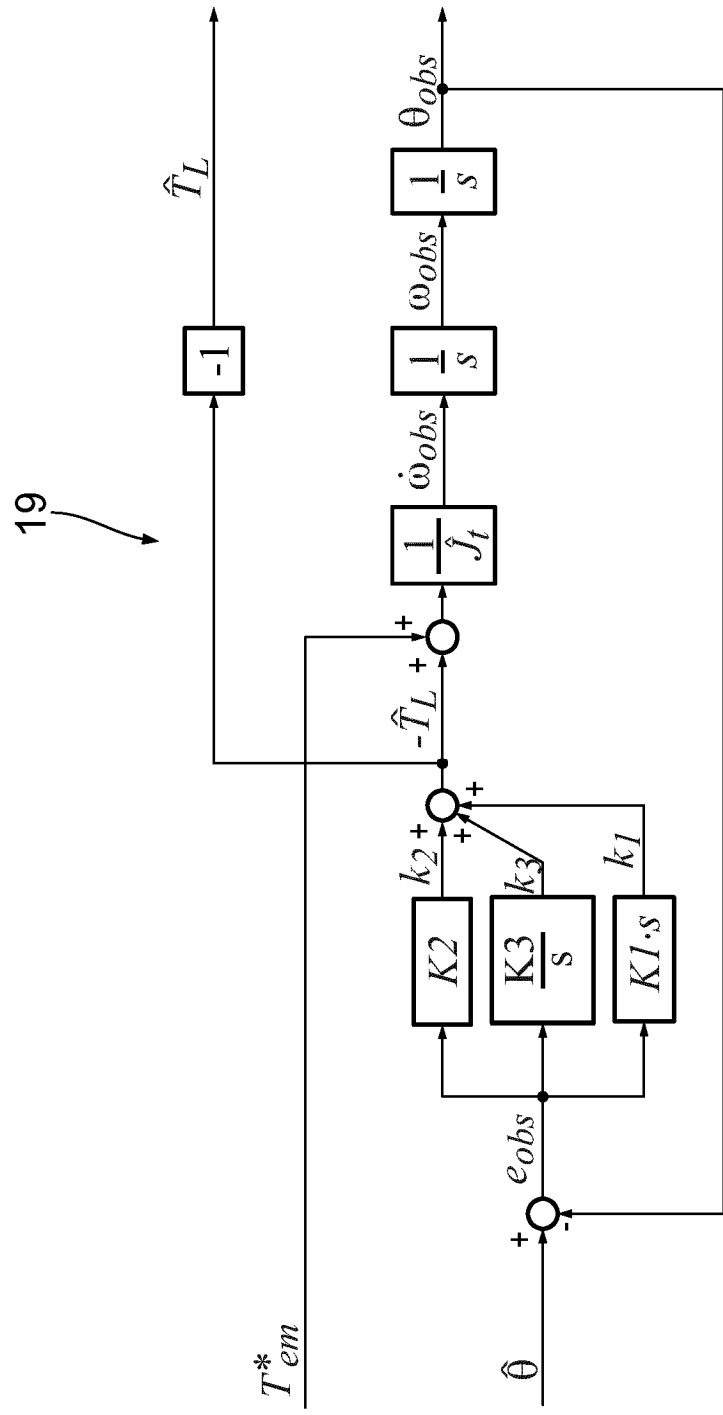


Fig. 4

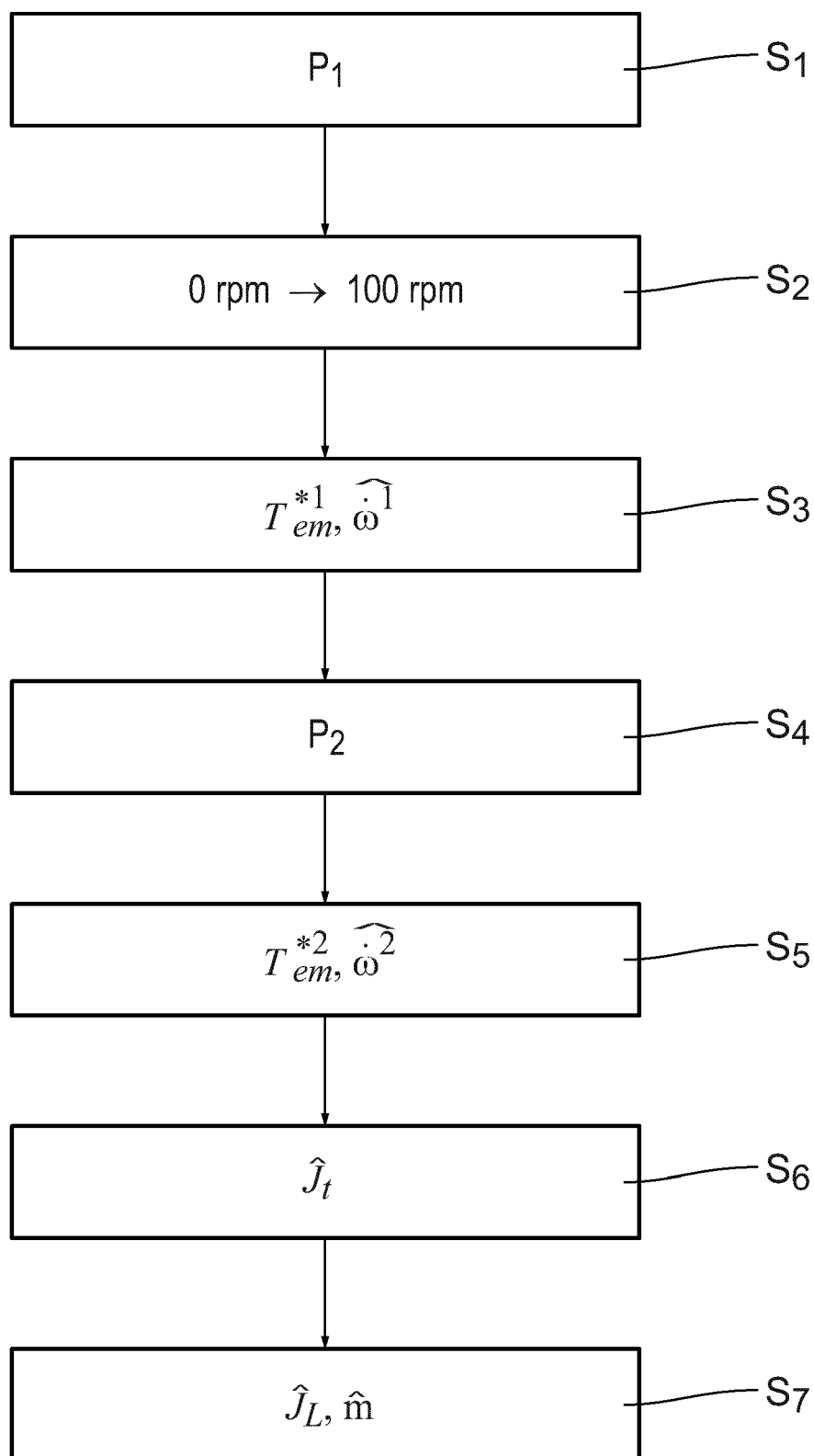


Fig. 5

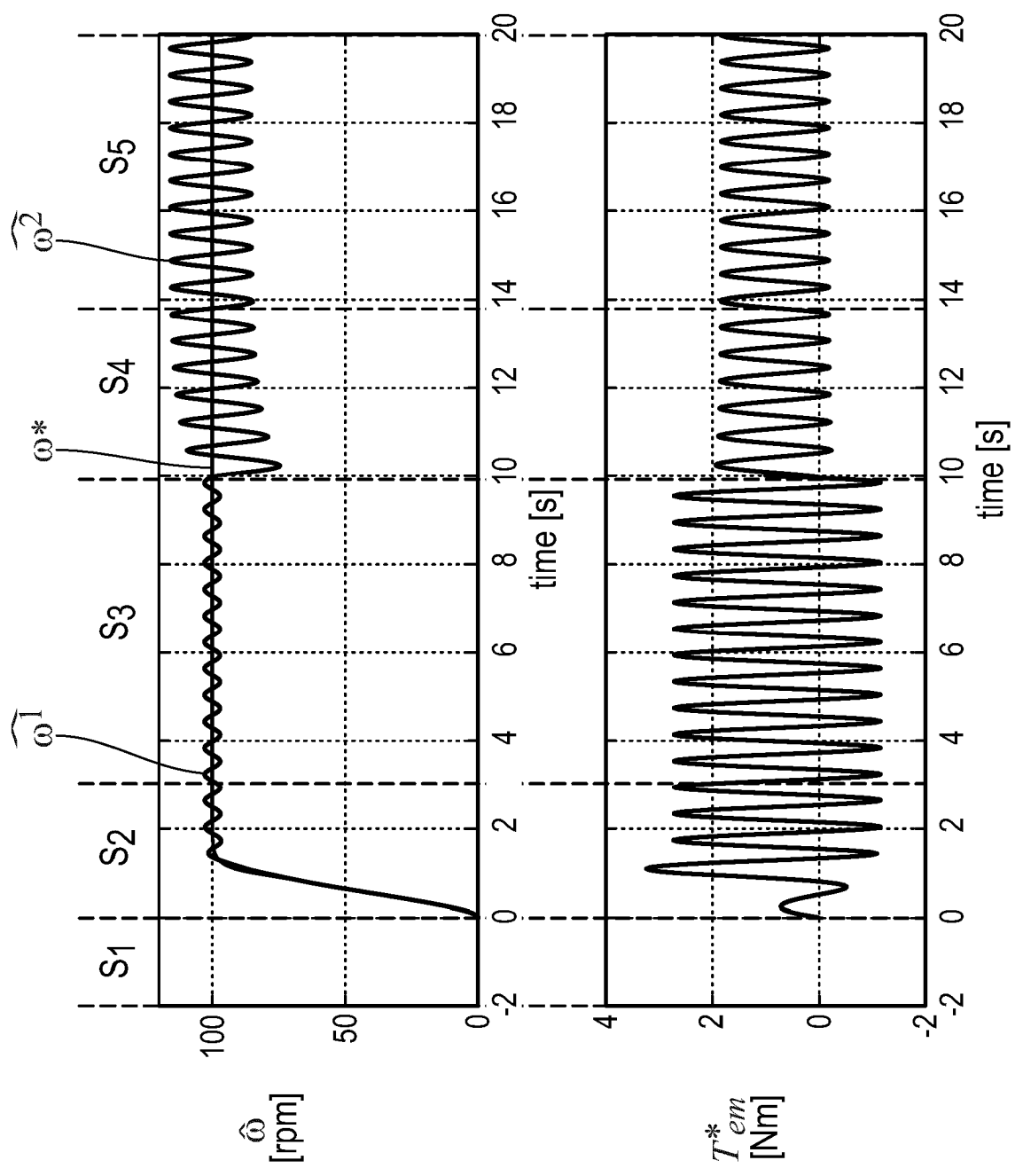


Fig. 6

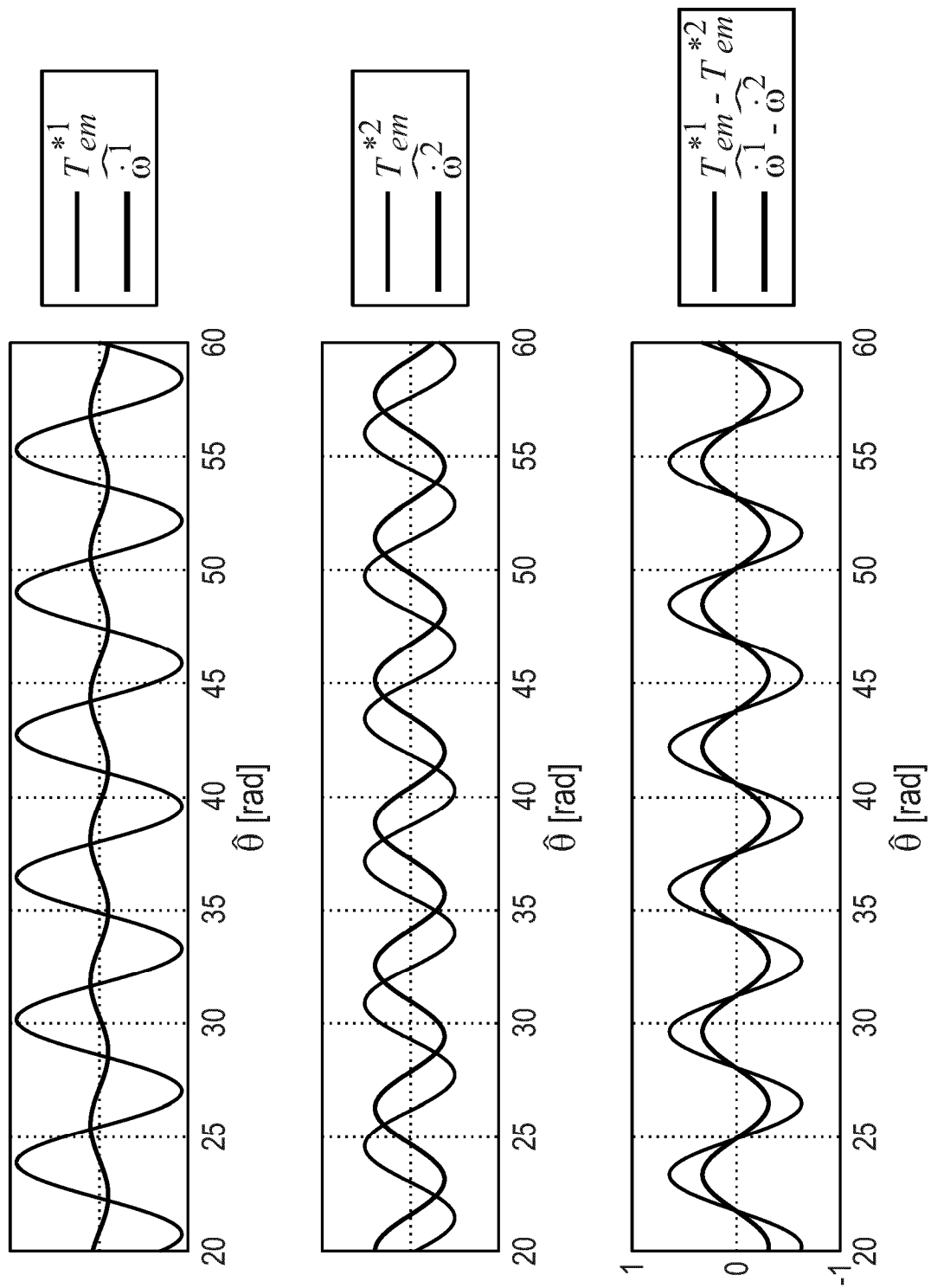


Fig. 7

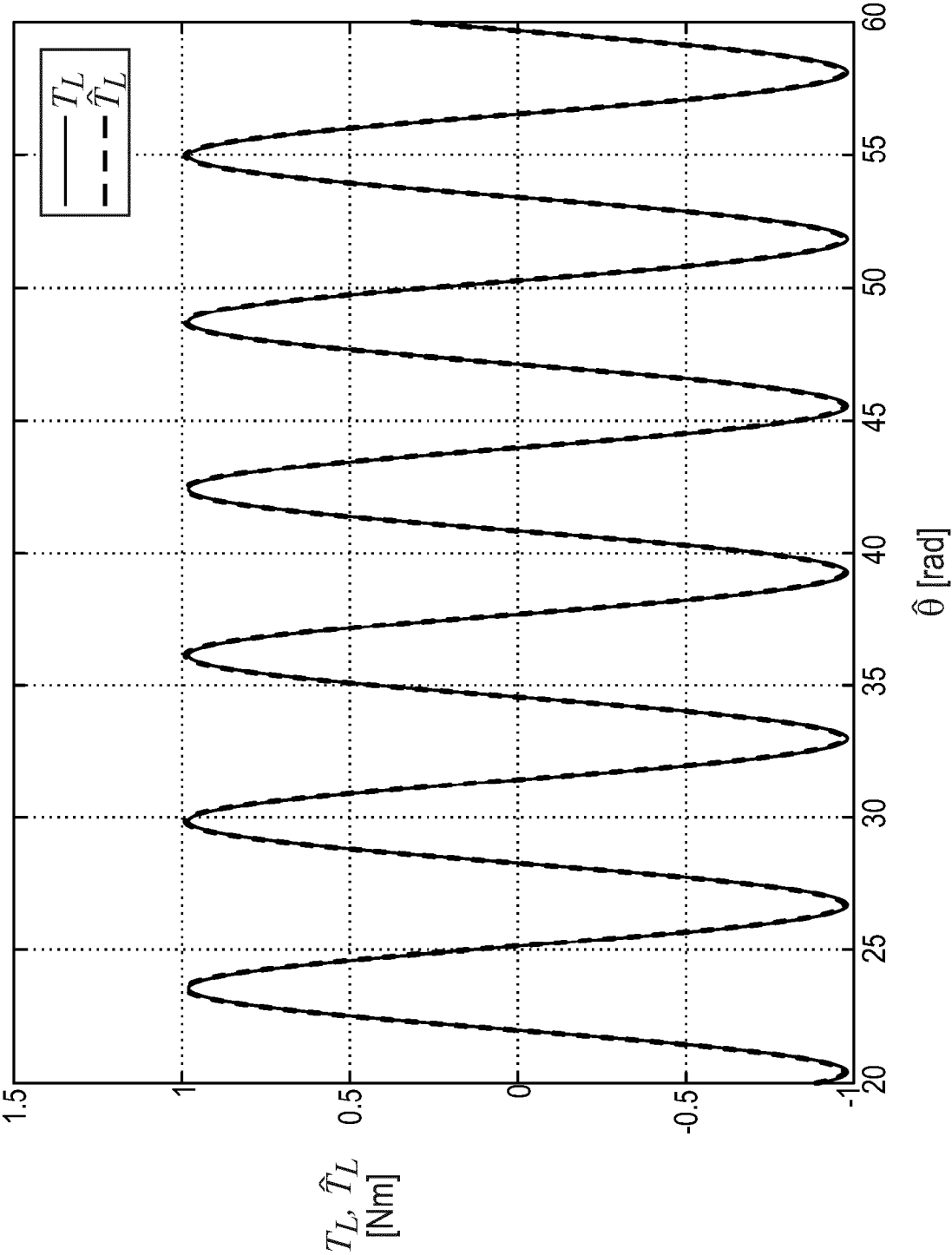


Fig. 8

REFERENCES CITED IN THE DESCRIPTION

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