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(54) LAUNDRY TREATMENT MACHINE AND METHOD TO OPERATE A LAUNDRY TREATMENT MACHINE

(57) A laundry treatment machine comprises a drum (5) which is rotated around a rotational axis (10) by means of a drive motor. The rotational axial (10) defines vertical plane (E_{V1}). The laundry treatment machine comprises at least one unbalance sensor (14, 15) and at least one position sensor (16). The at least one unbalance sensor (14, 15) and the vertical plane (E_{V1}) enclose an angle α, wherein $0° < \alpha < 90°$ and/or the at least one position sensor comprises a detector and at least one part (18) to be detected, wherein the at least one part (18) to be detected is arranged at the drum (5). The sensors (14, 15, 16) provide measurement signals with a high signal quality which enable a reliable and accurate estimation of a load (L).

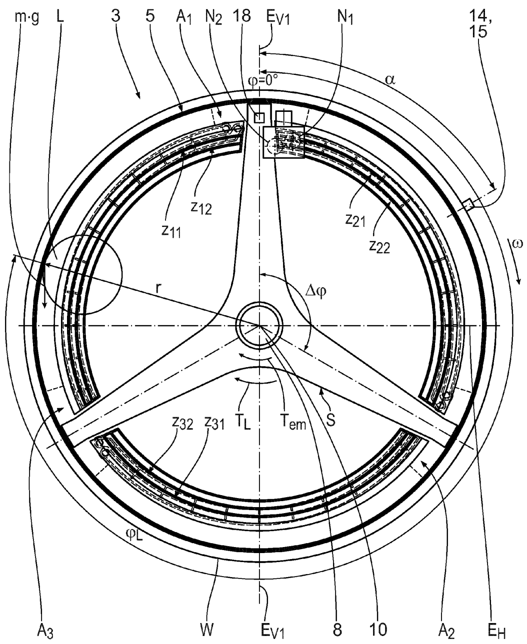

Fig. 2

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Description

[0001] The invention relates to a laundry treatment machine. Furthermore, the invention relates to a method to operate a laundry treatment machine. For example, the laundry treatment machine is a washing machine or a drying machine or a combined washing and drying machine.

[0002] The washing unit of a laundry treatment machine 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. 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 an unbalance of the load is required in order to avoid a mechanical impact between the tub and the cabinet when the resonance region is crossed. The unbalance estimation has to be performed before the resonance region is crossed.

[0003] EP 1736 589 A2 discloses a washing machine with a measurement device for detecting an unbalance of the drum. The washing machine comprises two acceleration sensors which are arranged in a twelve o'clock position at a front side and a rear side of the drum. Furthermore, the washing machine comprises an angular speed sensor with a detector which detects marks at a rotating body. A controller of the washing machine determines the position and the magnitude of the unbalance from the measurement values.

[0004] It is an object of the present invention to provide a laundry treatment machine which enables to estimate a behaviour of a load in an easy, reliable and accurate manner.

[0005] This object is achieved by a laundry treatment machine with the features of claim 1. In order to get a reliable and accurate estimation of the load behaviour it is essential that the at least one unbalance sensor and/or the at least one position sensor provides a measurement signal with a high signal quality. An increased signal quality results in an increased estimation accuracy. Therefore, it is important that disturbances are reduced in each measurement signal and a high signal-to-noise ratio is achieved.

[0006] The at least one unbalance sensor is arranged at a position such that for the angle α applies: $0° < \alpha < 90°$, in particular $15° \leq \alpha \leq 75°$, and in particular $30° \leq \alpha \leq 60°$. For each unbalance sensor the angle α is defined in a projection plane which runs perpendicular to the axis of rotation. In theory, the signal quality of the measurement signal of the at least one unbalance sensor would be best at an angle of $\alpha = 90°$, since at this angle an unbalanced load generates a maximum torque. However, the suspension system changes this angular position of high signal quality. Furthermore, an angular position of $\alpha = 90°$ results in a decreased drum size or in an increased risk of a mechanical impact during operation of the laundry treatment machine. Since $0° < \alpha < 90°$ applies, the at least one unbalance sensor provides a good signal quality without the above described disadvantages.

[0007] Preferably, the rotational axis defines a horizontal plane and the at least one unbalance sensor is arranged above and/or below this horizontal plane. Preferably, the at least one unbalance sensor is arranged between a 0 o'clock position and a 3 o'clock position and/or between a 0 o'clock position and a 9 o'clock position and/or between a 6 o'clock position and a 3 o'clock position and/or between a 6 o'clock position and a 9 o'clock position. Preferably, the at least one unbalance sensor is arranged at a tub of the laundry treatment machine. Preferably, the at least one unbalance sensor is at least one of an accelerometer sensor and an optical sensor.

[0008] The signal quality of the measurement signal of the at least one position sensor is increased, because the at least one part to be detected is arranged directly at the drum. Preferably, the laundry treatment machine has exactly one angular position sensor. Preferably, the at least one part to be detected is arranged at a rear side of the drum. Preferably, the at least one position sensor comprises a number of k parts to be detected wherein $1 \leq k \leq 32$, in particular $2 \leq k \leq 16$, and in particular $4 \leq k \leq 8$. The parts to be detected are attached at the drum at equal angular distances. The detector is arranged at a tub and/or at a cabinet of the laundry treatment machine. The attachment of the at least one part to be detected directly at the drum results in a decreased amount of mechanical disturbances and in an increased signal quality. The at least one position sensor enables an easy assembly.

[0009] Preferably, the at least one position sensor is a once per revolution sensor with a detector and exactly one part to be detected. The exactly one part is mounted at a defined angular position at the drum such that the at least one position sensor provides an absolute angular position of the drum. Preferably, the detector is designed as Hall sensor or reed switch. Preferably, the at least one part to be detected is designed as a magnet.

[0010] The at least one unbalance sensor and the at least one position sensor can be used independently of each other or in combination and result both in an increase of signal quality such that the laundry treatment machine enables an estimation of the load behaviour in any easy, reliable and accurate manner.

[0011] Preferably, the laundry treatment machine comprises a washing unit which is suspended to a cabinet by means of a suspension system. The suspension system comprises springs and dampers. A tub of the washing unit is suspended to the cabinet by means of the springs and the dampers. The drum is arranged within the tub. The drive motor may be connected to the drum directly or via a belt drive.

[0012] A laundry treatment machine according to claim 2 ensures an easy, reliable and accurate estimation of the load behaviour. A base of the laundry treatment machine defines a base plane. The horizontal plane runs in parallel to the base plane. Preferably, the at least one unbalance sensor is arranged between a 0 o'clock position and a 3 o'clock position and/or between a 0 o'clock position and a 9 o'clock position.

[0013] A laundry treatment machine according to claim 3 ensures an easy, reliable and accurate estimation of the load behaviour. The laundry treatment machine has a centre of gravity. The centre of gravity defines a vertical plane which runs perpendicular to the axis of rotation. This vertical plane defines a front side and a rear side. Preferably, the first unbalance sensor and the second unbalance sensor are arranged at different sides of this vertical plane, namely at the front side and at the rear side. Preferably, the first unbalance sensor and the second unbalance sensor have a distance from each other in an axial direction. The unbalance sensors enable to estimate the behaviour of load which is unequally distributed in a direction parallel to the axis of rotation. The unbalance sensors may have equal or different measuring principles.

[0014] A laundry treatment machine according to claim 4 ensures an easy, reliable and accurate estimation of the load behaviour. The artificial neural network has an input layer, at least one hidden layer and an output layer. Preferably, the artificial neural network has a number M of hidden layers, wherein $1 \leq M \leq 5$, in particular $2 \leq M \leq 4$. Preferably, the artificial neural network is designed as feedforward neural network.

[0015] A laundry treatment machine according to claim 5 ensures an easy, reliable and accurate estimation of the load behaviour. An input layer of the artificial neural network provides at least one signal input. Preferably, the at least one signal input is connected to a signal output of the at least one unbalance sensor and/or a signal output of the at least one position sensor and/or a signal output to provide a torque signal. Preferably, the torque signal is provided by an estimation of the drive torque or by a desired drive torque of a speed controller of the drive motor. The output signal of the speed controller characterizes the desired electromagnetic drive torque of the drive motor and can be used to estimate the drive torque.

[0016] A laundry treatment machine according to claim 6 ensures an easy, reliable and accurate estimation of the load behaviour. An output layer of the artificial neural network has at least one signal out. Depending on the training of the artificial neural network the at least one signal output provides an estimation of at least one of a mass of the load, an angular position of the load, an axial position of the load, a force acting on the drum and a torque acting on the drum. The force and the torque are caused by the drive motor and the load. The at least one signal output provides at least one output signal which can be used to estimate the dry load at the beginning of the washing cycle in order to set the amount of resources and energy, the wet load at the end of the washing cycle and/or the position and magnitude of the unbalanced load.

[0017] A laundry treatment machine according to claim 7 ensures an easy, reliable and accurate estimate of the load behaviour. The drive motor is directly connected via a drive shaft with the drum. The drive shaft provides a stiff connection such that the drive torque is acting directly on the drum. Consequently, the torque signal accurately corresponds to the drive torque. This results in an accurate and reliable estimation of the load behaviour, in particular by means of the artificial neural network.

[0018] A laundry treatment machine according to claim 8 ensures an easy, reliable and accurate estimation of the load behaviour. The compensation unit is used to compensate an unbalanced load depending on the estimated behaviour. Additionally, the compensation unit can be used to perform a training of the artificial neural network. The compensation unit comprises several balancers which can be filled individually with water. By filling an amount of water in at least one selected balancer in a defined manner the compensation unit can simulate an unbalanced load. This load is known such that the artificial neural network can be trained. Preferably, each balancer is divided into at least two subchambers which can be filled individually with water. By filling a subchamber at a front side and/or a subchamber at a rear side with an amount of water in a defined manner the artificial neural network can be trained to estimate an axial position of an unbalanced load. The compensation unit comprises at least one injection valve, preferably at least two injection valves, to fill water into the at least one balancer, in particular into at least one subchamber at a front side and/or rear side. Each balancer is connected with at least one supply channel, preferably with two supply channels to supply the water from the at least one injection valve to the at least one balancer.

[0019] Furthermore, it is an object of the present invention to provide a method to operate a laundry treatment machine which enables an easy, reliable and accurate estimation of a load behaviour.

[0020] This object is achieved by a method comprising the steps of claim 9. The advantages of the method according to the invention correspond to the advantages already described in connection with the laundry treatment machine according to the invention.

[0021] A method according to claim 10 ensures an easy, reliable and accurate estimation of the load behaviour. In order to avoid a mechanical impact the laundry treatment machine is operated below a resonance frequency and an angular speed of resonance during estimation of the load behaviour and/or training of an artificial neural network. The angular speed ω is lower than a critical resonance frequency, in particular lower than 300 rpm. Preferably, 50 rpm $\leq \omega \leq$ 250 rpm, in particular 75 rpm $\leq \omega \leq$ 200 rpm, and in particular 100 rpm $\leq \omega \leq$ 150 rpm.

[0022] A method according to claim 11 ensures an easy, reliable and accurate estimation of the load behaviour. Preferably, an artificial neural network is used to estimate the load behaviour. The artificial neural network is implemented into the control unit and has to be trained in advance to be able to estimate the load behaviour. In order to train the artificial neural network at least one known unbalanced load is positioned in the drum. The artificial neural network is trained by minimizing a quality function which comprises at least one error between the known behaviour of the provided load and a behaviour of the provided load which is estimated by means of the artificial neural network.

[0023] A method according to claim 12 ensures an easy, reliable and accurate estimation of the load behaviour. The compensation unit is used to train the artificial neural network. At least one balancer of the compensation unit is filled with an amount of water in a defined manner such that a known unbalanced load is created. Afterwards the artificial neural network is trained to estimate the behaviour of the known unbalanced load. By using the compensation unit the training of the artificial neural network can be fully automated. This results in a considerable saving of time to train the artificial neural network.

[0024] A method according to claim 13 ensures an easy, reliable and accurate estimation of the load behaviour. The accuracy of the estimation can be increased by increasing the number N of known unbalanced loads which are used to train the artificial neural network. Preferably, $2 \leq N \leq 500$, in particular $10 \leq N \leq 400$, in particular $20 \leq N \leq 300$, and in particular $50 \leq N \leq 200$. Preferably, the known unbalanced loads are different in their mass, in their angular position and/or in their axial position.

[0025] A method according to claim 14 ensures an easy, reliable and accurate estimation of the load behaviour. The artificial neural network comprises weight parameters which have to be adapted during the training process. The weight parameters are adapted by minimising a quality function. The quality function comprises at least one error between a known behaviour of the provided load and an estimated behaviour of the provided load. For example, to estimate the mass of the load the corresponding quality function comprises an error between the known mass and an estimated mass.

[0026] A method according to claim 15 ensures an easy, reliable and accurate estimation of the load behaviour. The trained artificial neural network is used to estimate the behaviour of a load caused by the laundry inside of the drum during normal operation of the laundry treatment machine. The estimated behaviour of the load can be used to compensate the unbalance caused by the load by means of the compensation unit. In order to compensate the unbalanced load at least one balancer is filled with water such that the unbalance of the load is decreased. By compensating the unbalance of the load the mechanical stress on the drum and the bearings is reduced and a mechanical damage is prevented.

[0027] 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,

Fig.2 shows a rear side of a washing unit of the laundry treatment machine in Fig. 1,

Fig. 3 shows a perspective view of a compensation unit of the laundry treatment machine in Fig. 1,

Fig. 4 shows the design of an artificial neural network which is implemented into a control unit of the laundry treatment machine in Fig. 1,

Fig. 5 shows a flow chart of a method to operate the laundry treatment machine in Fig. 1, and

Fig. 6 shows a schematic block diagram of the artificial neural network during a training process.

[0028] 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. The drum 5 is mounted in a rotatable manner to the tub 4. The tub 4 comprises a front wall F, a rear wall R and a circumferential wall W which is connected to the front wall F and the rear wall R. The drum 5 is connected via a drive shaft 8 with a drive motor 9. The drive motor 9 is mounted at the rear wall R of the tub 4. The drive motor 9 rotates the drum 5 around a horizontal rotational axis 10 by exerting a drive torque T_{em}.

[0029] The cabinet 2 comprises a base 11, four side walls 12 and a top cover 13. The base 11 defines a base plane E_B which runs in parallel to a horizontal x-direction and a horizontal y-direction. The rotational axis 10 and the base plane E_B define a vertical plane E_{V1}. The vertical plane E_{V1} runs perpendicular to the base plane E_B. The vertical plane E_{V1} runs in parallel to the horizontal x-direction and a vertical z-direction. The x-direction, the y-direction and the z-direction run in pairs perpendicular to each other and form a Cartesian coordinate system.

[0030] The washing machine 1 comprises a first unbalance sensor 14, a second unbalance sensor 15 and a position sensor 16. The first unbalance sensor 14 is mounted to the circumferential wall W adjacent to the front wall F, whereas the second unbalance sensor 15 is mounted to the circumferential wall W adjacent to the rear wall R. The first unbalance sensor 14 determines a movement of the washing unit 3 transverse to the rotational axis 10 at the front wall F and provides a first unbalance signal a_1, whereas the second unbalance sensor 15 determines a movement of the washing unit 3 transverse to the rotational axis 10 at the rear wall R and provides a second unbalance signal a_2.

[0031] Fig. 2 shows the washing unit 3 without the rear wall R of the tub 4. The vertical plane E_{V1} and each of the unbalance sensors 14, 15 enclose an angle a, wherein $0° < \alpha < 90°$, in particular $15° \leq \alpha \leq 75°$, and in particular $30° \leq \alpha \leq 75°$. For each unbalance sensor 14, 15 the angle α is defined in a projection plane, wherein the rotational axis 10 runs perpendicular to each projection plane. The unbalance sensors 14, 15 are arranged in the z-direction above a horizontal plane E_H. The horizontal plane E_H includes the rotational axis 10 and runs in parallel to the base plane E_B. The first unbalance sensor 14 and the second unbalance sensor 15 have a distance from each other in the x-direction and are mounted at the tub 4 at different sides of a vertical plane E_{V2}. The vertical plane E_{V2} and the rotational axis 10 run perpendicular to each other, whereas the vertical plane E_{V2} includes a centre of gravity G of the washing unit 3. The first unbalance sensor 14 and the second unbalance sensor 15 are uniaxial accelerometer sensors.

[0032] The position sensor 16 is a once per revolution sensor. The position sensor 16 comprises a detector 17 and a part 18 to be detected. The detector 17 is attached to the rear wall R of the tub 4. The drum 5 comprises a front wall f, a rear wall r and a circumferential wall w which is connected to the front wall f and the rear wall r. The drum 5 further comprises a starlike stiffening member S which is attached to the rear wall r. The part 18 to be detected is attached at the stiffening member S. The position sensor 16 provides an absolute angular position signal φ of the drum 5.

[0033] The washing machine 1 comprises a compensation unit 19. The compensation unit 19 comprises three balancers A_1, A_2, A_3 which move the laundry and can be filled with water. The balancers A_1, A_2, A_3 are mounted in equal angular distances $\Delta\varphi$ to an inner side of the drum 5. Each balancer A_1, A_2, A_3 is divided by partition walls p into subchambers s. Adjacent subchambers s are connected to each other via a through hole t. The subchambers s can be successively filled with water from the front wall f and/or the rear wall r. Each balancer A_1, A_2, A_3 is filled with water via supply channels Z_{11}, Z_{12}, Z_{21}, Z_{22}, Z_{31}, Z_{32}, wherein the supply channels Z_{11}, Z_{21}, Z_{31} serve to fill the balancers A_1, A_2, A_3 from the rear wall r and the supply channels Z_{12}, Z_{22}, Z_{32} serve to fill the balancers A_1, A_2, A_3 from the front wall f. The water is injected into the supply channels Z_{11}, Z_{21}, Z_{31} via a first nozzle N_1 and into the supply channels Z_{12}, Z_{22}, Z_{32} via a second nozzle N_2. The injected water is forced into the balancers A_1, A_2, A_3 by a centrifugal force which is caused by a rotation of the drum 5.

[0034] Furthermore, the washing machine 1 comprises a control unit 20 to control the operation. The control unit 20 comprises a speed controller 21 and a torque controller 22. The torque controller 22 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 22 is a PI controller. The speed controller 21 is part of an outer control loop or a speed control loop to control the angular speed ω of the drive motor 9. For example, the speed controller 21 is a PI controller. The speed controller 21 is provided with a difference of a desired angular speed and measured or estimated angular speed ω of the drive motor 9. The output signal of the speed controller 21 is a desired drive torque T^*_{em} which is used as an input signal for the torque controller 22.

[0035] The control unit 20 comprises an artificial neural network NN which serves to estimate the behaviour of a load L. The load L is caused by the laundry inside of the drum 5. The artificial neural network NN has an input layer L_I, two hidden layers L_{H1}, L_{H2} and an output layer L_O. The input layer L_I has four neurons which provide four signal inputs to receive four input signals s_1, s_2, s_3, s_4. Furthermore, the output layer L_O has five neurons with five signal outputs. The five signal outputs provide five output signals o_1, o_2, o_3, o_4, o_5. The hidden layers L_{H1}, L_{H2} each comprise five neurons. Each neuron of the input layer L_I is connected with each neuron of the first hidden layer L_{H1}. Each neuron of the first hidden layer L_{H1} is connected to each neuron of the second hidden layer L_{H2}. Furthermore, each neuron of the second hidden layer L_{H2} is connected to each neuron of the output layer L_O. The artificial neural network NN is designed as a feedforward network.

[0036] In general, each neuron can be described by the equation

$$o = f\left(w_0 + \sum_{i=1}^{n} x_i \cdot w_i\right),$$

wherein

- x_i denotes the input signals of the neuron,
- w_i denotes weight parameters assigned to each input signal,
- w_0 denotes a bias weight parameter,
- n denotes the number of input signals,
- i denotes an index,
- f denotes a transfer function and
- o denotes an output signal of the neuron.

[0037] The first unbalance sensor 14 provides the first unbalance signal a_1 which characterizes a movement of the washing unit 3 transverse to the rotational axis 10 near the front wall F. Correspondingly, the second unbalance sensor 15 provides the second unbalance signal a_2 which characterizes a movement of the washing unit 3 transverse to the rotational axis 10 near the rear wall R. The first unbalance signal a_1 is transferred into a frequency domain by calculating a fourier transformation. The first input signal s_1 of the artificial neural network NN is equal to the transferred first unbalance signal a_1. Correspondingly, the second unbalance signal a_2 is transferred into a frequency domain by calculating a fourier transformation. The second input signal s_2 of the artificial neural network NN is equal to the transferred second unbalance signal a_2.

[0038] The position sensor 16 provides the position signal φ. The position sensor 16 is connected to a third signal input such that the third input signal s_3 is equal to the position signal φ.

[0039] The speed controller 21 is connected to a fourth signal input such that the fourth input signal s_4 is equal to the desired drive torque T^*_{em}.

[0040] The artificial neural network NN is trained such that a first output signal o_1 estimates the mass m of the load L, a second output signal o_2 estimates an axial position X_L of the load L, a third output signal o_3 estimates an angular position φ_L of the load L, a fourth output signal o_4 estimates a torque T acting on the drum 5 and a fifth output signal o_5 estimates a force F acting on the drum 5. The torque T depends on the drive torque T_{em} and a toque T_L caused by the load L such that $T = T_{em} + T_L$. The force F can be described by $F = T/r$, wherein r is the radius of the drum 5. For the torque T_L caused by the load L applies: $T_L = m \cdot g \cdot r \cdot \sin((\varphi_L)$, wherein g denotes the gravitational acceration.

[0041] In the following the operation of the washing machine 1 is described in detail.

[0042] First of all, the artificial neural network NN has to be trained. In a first step S_1 a known unbalanced load L is generated by means of the compensation unit 19. At least one of the balancers A_1, A_2, A_3 is filled with a defined amount of water such that an unbalanced load L is simulated. The load L has a known mass m, a known axial position X_L, a known angular position φ_L such that the drive motor 9 and the load L create a known torque T and a known force F.

[0043] In a second step S_2 the washing machine 1 is operated and the neural network NN is trained. The training process is shown in fig. 6, wherein $\underline{s}$ is a vector of all input signals s_1 to s_4 and $\underline{o}$ is a vector of all output signals o_1 to o_5. The known load L provides desired output signals of the artificial neural network NN which are summarized in a vector $\underline{o}_L$. In order to train the artificial neural network NN error signals e_1 to e_5 are calculated which are summarized in a vector $\underline{e}$, wherein $\underline{e} = \underline{o} - \underline{o}_L$. By means of a quality function which comprises the error signals e_1 to e_5 the weight parameters w_0, w_i of the artificial neural network NN are adapted such that the quality function is minimized.

[0044] The steps S_1 and S_2 are repeated for a number N of known unbalanced loads L, wherein $2 \leq N \leq 500$. The known unbalanced loads L are different of each other with respect to their mass m, their axial positions x_L and their angular positions φ_L. By using the compensation unit 19 to train the artificial neural network NN, the training process can be automized.

[0045] In order to avoid the excitation of a resonance frequency, the training process takes place at an angular speed ω of the drum 5 which is lower than an angular speed of resonance, wherein in particular 50 rpm $\leq \omega \leq$ 250 rpm, in particular 75 rpm $\leq \omega \leq$ 200 rpm, and in particular 100 rpm $\leq \omega \leq$ 150 rpm.

[0046] After completion of the training process the artificial neural network NN can be used in a step S_3 to estimate the behaviour of an unknown load L during normal operation of the washing machine 1. In step S_3 the adaption of the weight parameters w_0, w_i is finished and disabled such that the weight parameters w_0, w_i are constant. Due to the trained artificial neural network NN the behaviour of the unknown load L, namely the output signals o_1 to o_5 according to fig. 4 can be estimated.

[0047] In a step S_4 the output signals o_1 to o_5 can be used to compensate the unbalance of the load L by means of the compensation unit 19. Depending on the estimated behaviour of the load L at least one of the balancers A_1, A_2, A_3 is filled with a suitable amount of water such that the unbalance of the load L is reduced. A compensation controller 23 determines the at least one balancer A_1, A_2, A_3, the amount of water and the nozzle N_1, N_2 to compensate the unbalanced load L.

[0048] Due to the angular position of the first unbalance sensor 14 and the second unbalance sensor 15 the unbalance signals a_1, a_2 have a good signal quality. Furthermore, due to their angular position the unbalance sensors 14, 15 do not reduce the available space between the tub 4 and the cabinet 2. The potion sensor 16 provides an absolute angular position φ of the drum 5 since exactly one part 18 to be detected is attached directly at the drum 5. Furthermore, the angular position φ has a high quality since the measurement is not affected by mechanical disturbances.

Claims

1. Laundry treatment machine with

   - a drum (5), wherein

     -- the drum (5) is rotatable around a rotational axis (10),
     -- the rotational axis (10) defines a vertical plane (E_{V1}),

   - a drive motor (9) to rotate the drum (5) around the rotational axis (10) by exerting a drive torque (T_{em}),
   - at least one unbalance sensor (14, 15) to determine a movement of the drum (5) transverse to the rotational axis (10),
   - at least one position sensor (16) to determine an angular position (φ) of the drum (5), and
   - a control unit (20) to estimate a behaviour of a load (L),

   characterized in
   that the at least one unbalance sensor (14, 15) and the vertical plane (E_{V1}) enclose an angle α,

wherein 0° < α < 90°,
and/or
that the at least one position sensor (16) comprises a detector (17) and at least one part (18) to be detected, wherein the at least one part (18) to be detected is arranged at the drum (5).

2. Laundry treatment machine according to claim 1, **characterized in that** the at least one unbalance sensor (14, 15) is arranged above a horizontal plane (E_H) which includes the rotational axis (10).

3. Laundry treatment machine according to claim 1 or 2, **characterized by** a first unbalance sensor (14) and a second unbalance sensor (15), which in particular have a distance from each other in a direction (x) parallel to the axis of rotation (10).

4. Laundry treatment machine according to at least one of the preceding claims, **characterized in that** the control unit (20) comprises an artificial neural network (NN) to estimate the behaviour of the load (L).

5. Laundry treatment machine according to claim 4, **characterized in that** the artificial neural network (NN) has at least one signal input, wherein at least one unbalance signal (a_1, a_2) of the at least one unbalance sensor (14, 15) and/or at least one angular position signal (φ) of the at least one position sensor (16) and/or a torque signal (T^*_{em}) characterizing the drive torque (T_{em}) is supplied to the at least one signal input.

6. Laundry treatment machine according to claim 4 or 5, **characterized in that** the artificial neural network (NN) has at least one signal output to provide an estimation of at least one of a mass (m) of the load (L), an angular position ((φL) of the load (L), an axial position (x_L) of the load (L), a force (F) acting on the drum (5) and a torque (T) acting on the drum (5).

7. Laundry treatment machine according to at least one of the preceding claims, **characterized in that** the drive motor (9) is directly connected to the drum (5).

8. Laundry treatment machine according to at least one of the preceding claims, **characterized by** a compensation unit (19) to compensate an unbalance of the load (L) depending on the estimated behaviour.

9. Method to operate a laundry treatment machine with the steps of:

- providing a laundry treatment machine (1) according to at least one of claims 1 to 8, and
- estimating the behaviour of the load (L) during operation of the laundry treatment machine (1).

10. Method according to claim 9, **characterized in that** the laundry treatment machine (1) is operated at an angular speed ω of the drum (5) which is lower than an angular speed of resonance, wherein in particular 50 rpm $\leq \omega \leq$ 250 rpm.

11. Method according to claim 9 or 10, **characterized by** the step of training an artificial neural network (NN).

12. Method according to claim 11, **characterized in that** a compensation unit (19) provides at least one known unbalanced load (L) to train the artificial neural network (NN).

13. Method according to claim 11 or 12, **characterized in that** the artificial neural network (NN) is trained automatically by providing a number N of unbalanced loads (L) which are different of each other and known, wherein in particular $2 \leq N \leq 500$.

14. Method according to at least one of claims 11 to 13, **characterized in that** weight parameters (w_0, w_i) of the artificial neural network (NN) are adapted by minimizing a quality function, wherein the quality function comprises at least one error (e_1 to e_5) between a known behaviour of the provided load (L) and an estimated behaviour of the provided load (L).

15. Method according to at least one of claims 11 to 14, **characterized in that** estimating the behaviour of the load (L) during operation of the laundry treatment machine (1) takes place by means of the trained artificial neural network (NN).

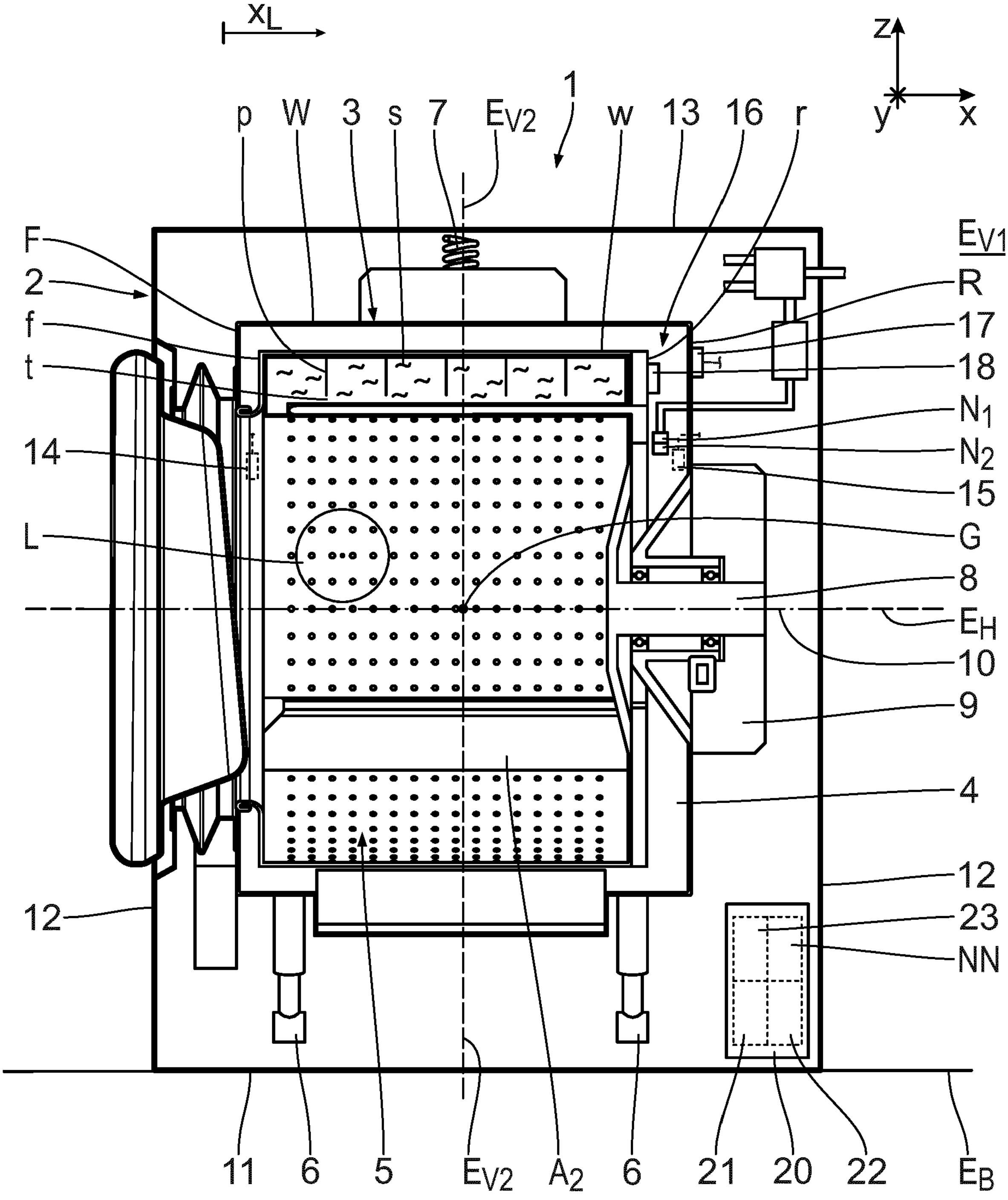
x_L
z
y
x
p
W
3
s
7
E_{V2}
1
w
13
16
r
E_{V1}
F
2
f
t
14
L
R
17
18
N_1
N_2
15
G
8
E_H
10
9
4
12
23
NN
12
11
6
5
E_{V2}
A_2
6
21
20
22
E_B

Fig. 1

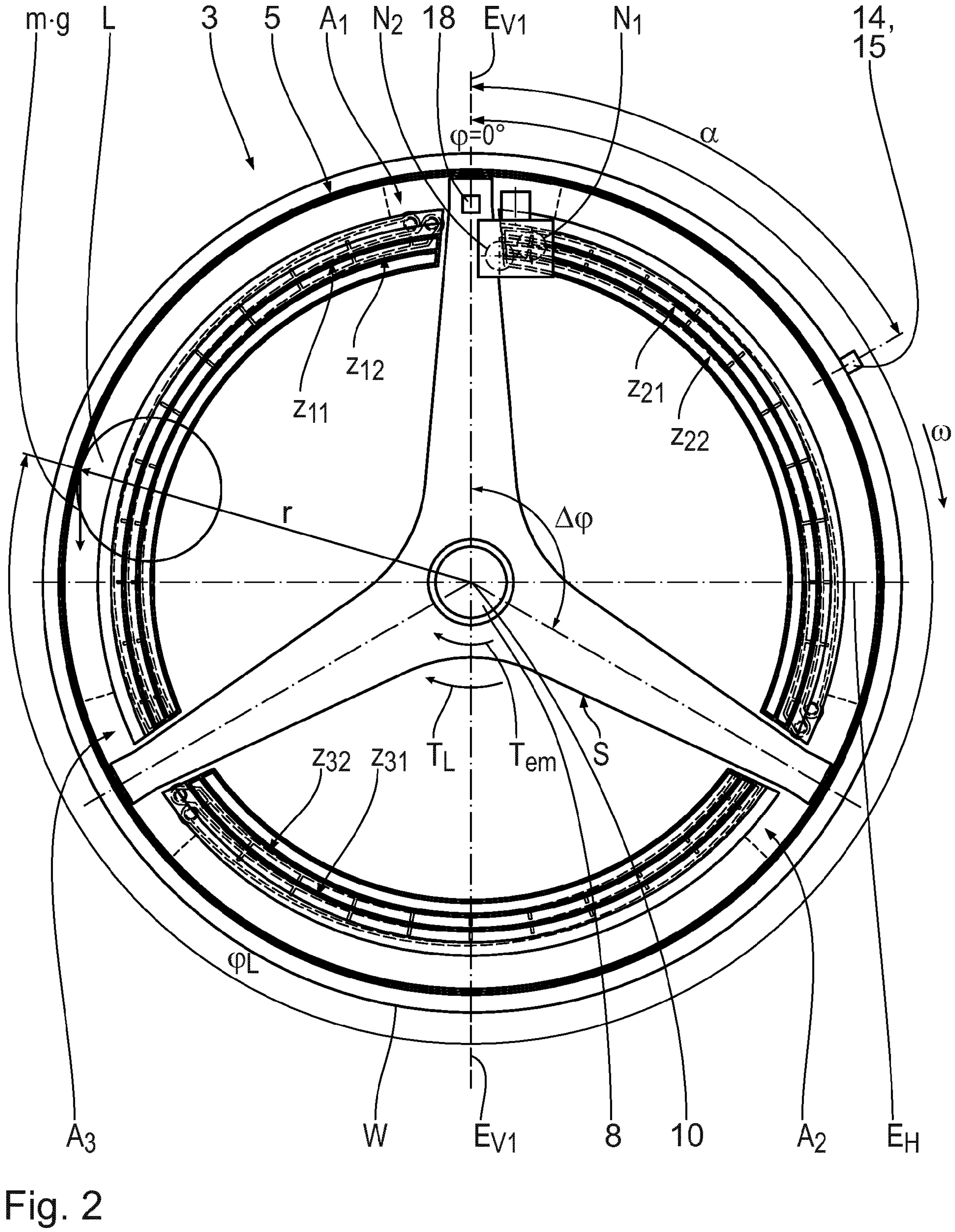
m·g
L
3
5
A1
N2
18
EV1
N1
14,
15
φ=0°
α
ω
z12
z11
z21
z22
r
Δφ
TL
Tem
S
z32
z31
φL
A3
W
EV1
8
10
A2
EH

Fig. 2

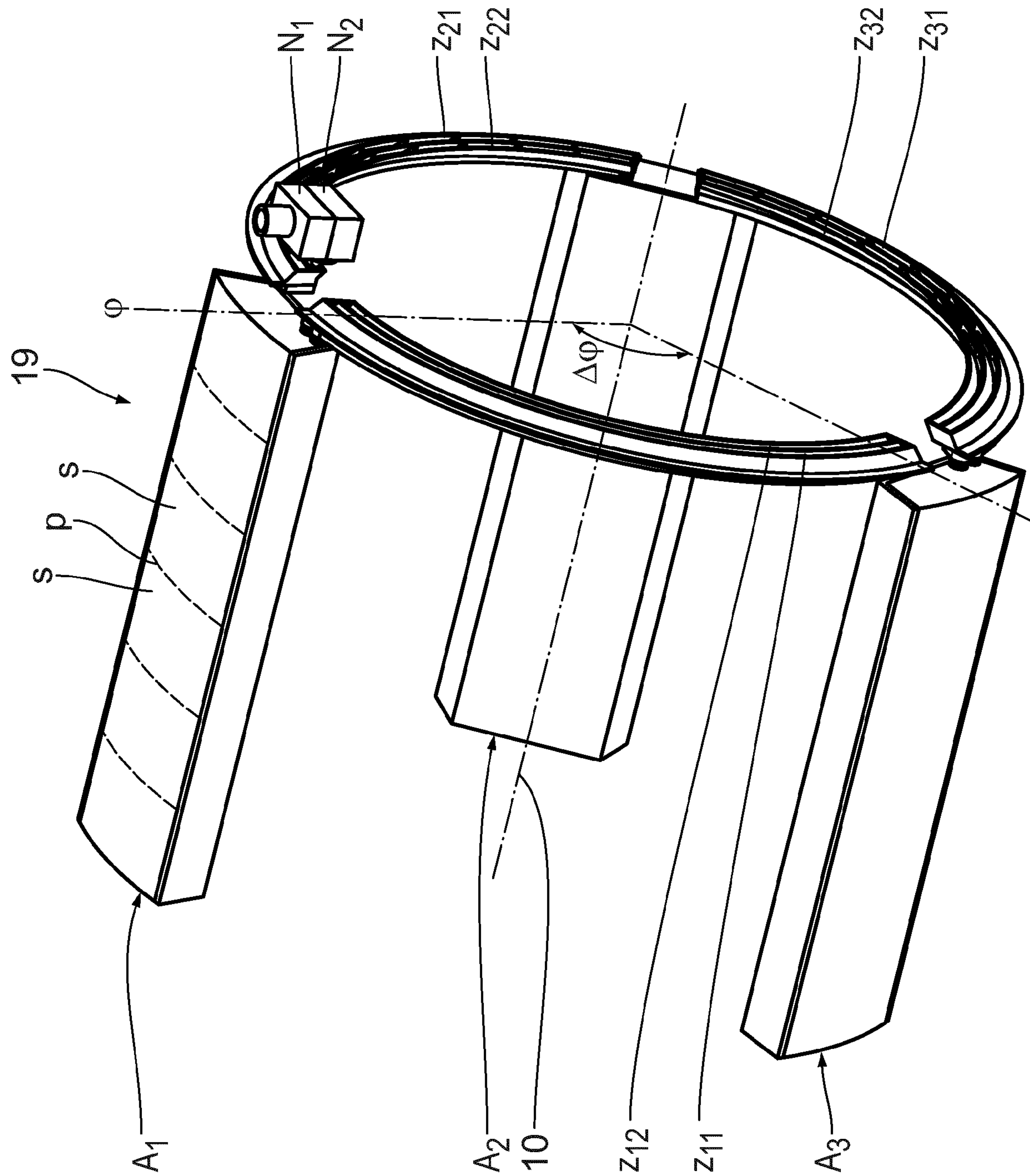

Fig. 3

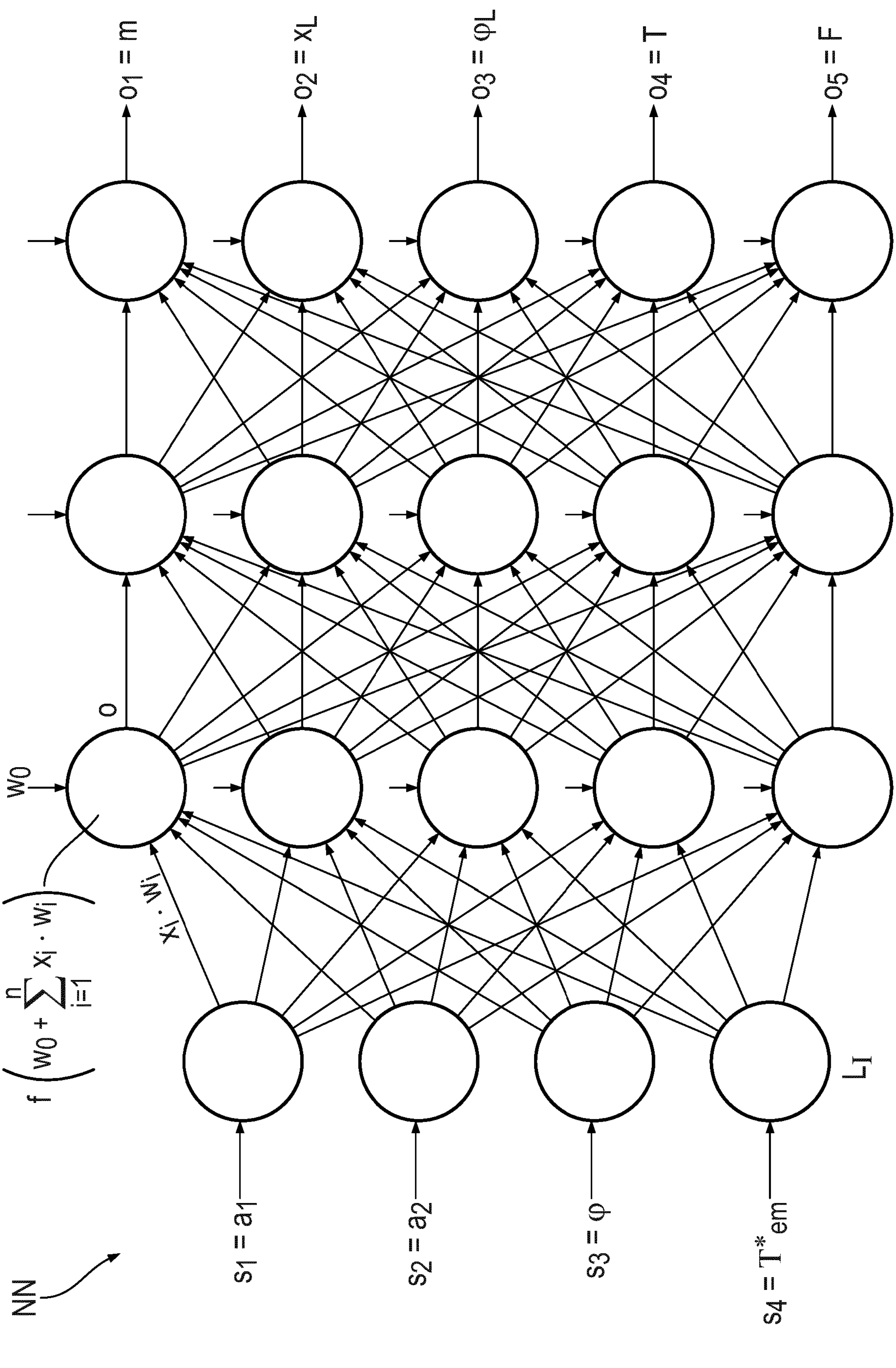
NN
$f\left(w_0 + \sum_{i=1}^{n} x_i \cdot w_i\right)$
$x_i \cdot w_i$
w_0
o
$s_1 = a_1$
$s_2 = a_2$
$s_3 = \varphi$
$s_4 = T^*_{em}$
L_I
L_{H1}
L_{H2}
L_O
$o_1 = m$
$o_2 = x_L$
$o_3 = \varphi_L$
$o_4 = T$
$o_5 = F$

Fig. 4

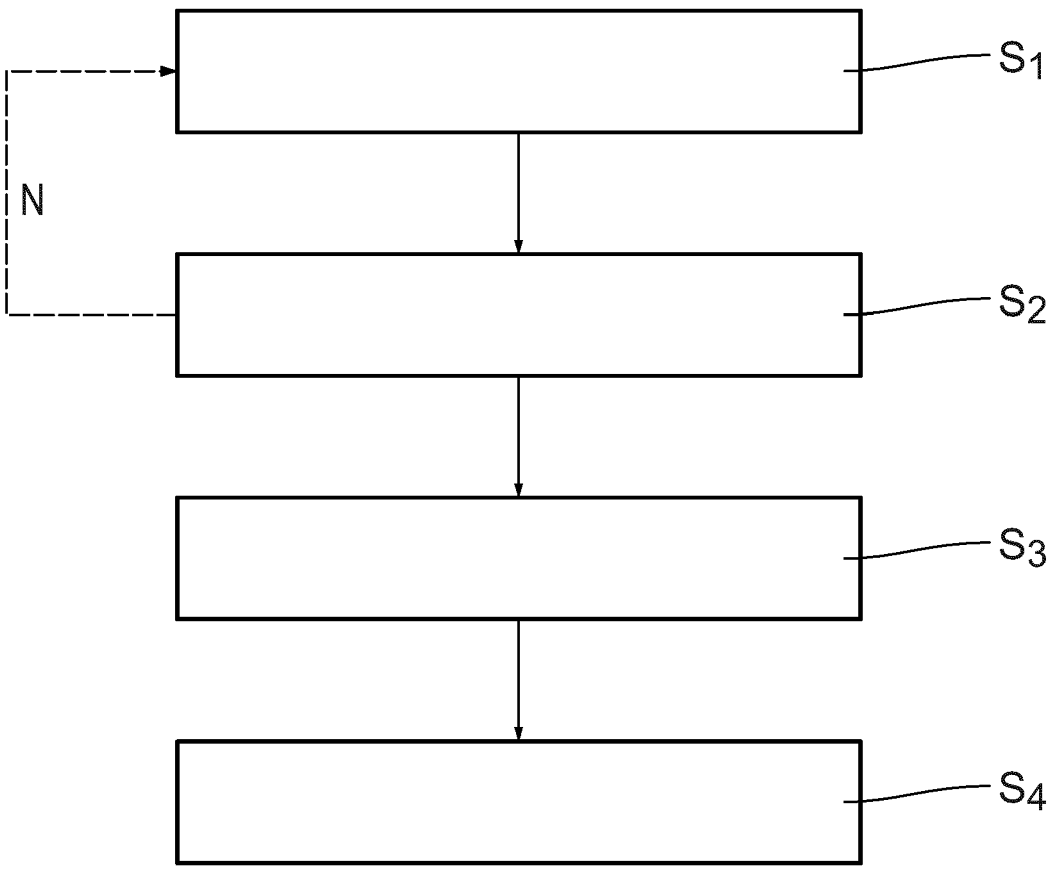

Fig. 5

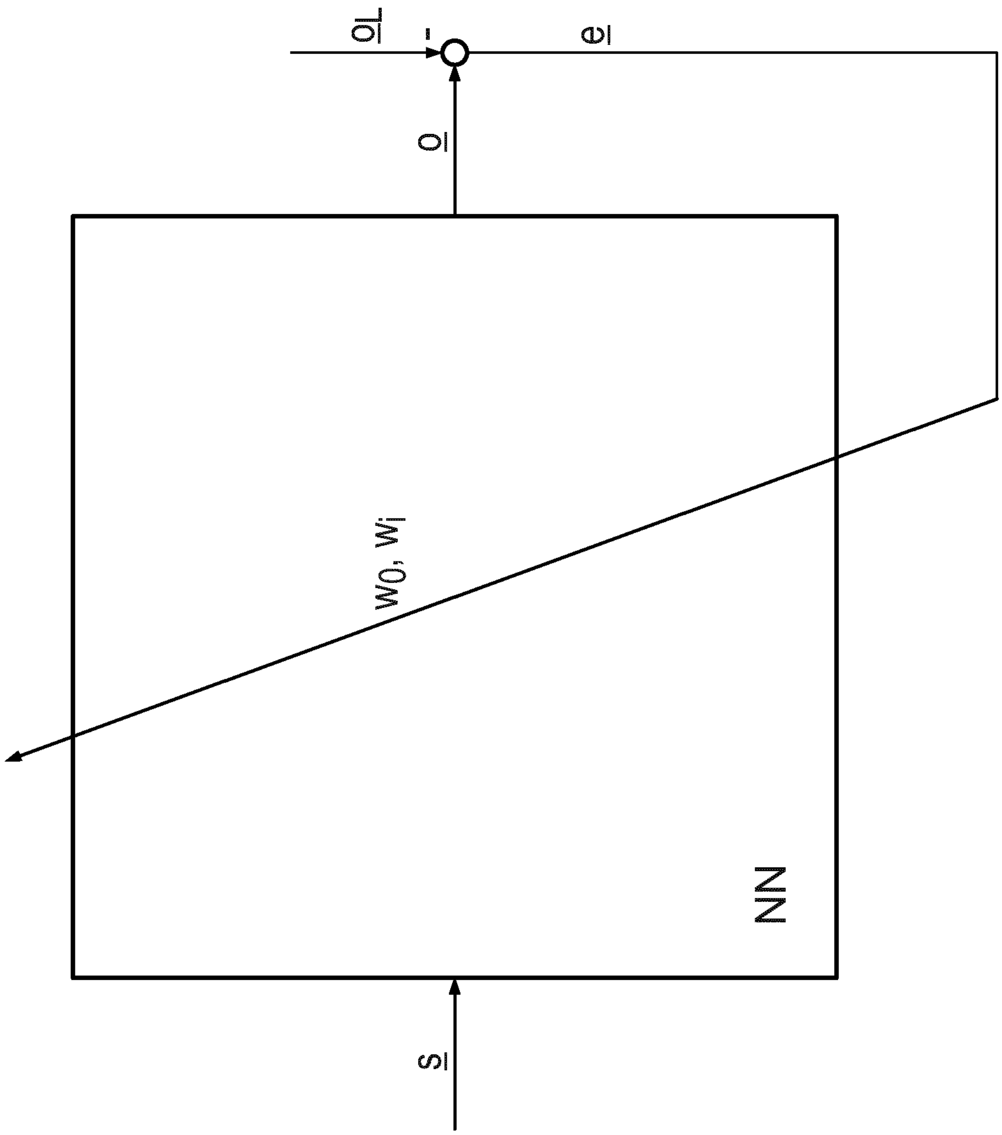

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 20 17 2486

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 2019/382935 A1 (LG ELECTRONICS INC [KR]) 19 December 2019 (2019-12-19) * paragraphs [0004], [0034], [0047], [0069], [0120], [0125], [0141], [0142], [0164]; claims; figures *	1-15	INV. D06F33/48 D06F34/16 ADD. D06F37/22 D06F103/24 D06F103/26
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Y A	US 2020/010999 A1 (LG ELECTRONICS INC [KR]) 9 January 2020 (2020-01-09) * paragraphs [0229], [0257]; claims; figures *	12-14 1-11,15	
A	US 2019/390389 A1 (LG ELECTRONICS INC [KR]) 26 December 2019 (2019-12-26) * the whole document *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)
D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	16 July 2020	Popara, Velimir

CATEGORY OF CITED DOCUMENTS

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16-07-2020

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