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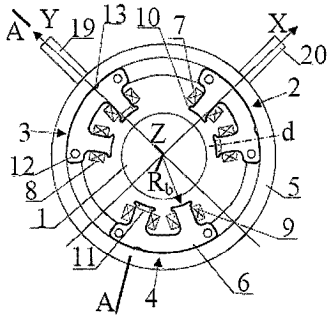


fig. 1

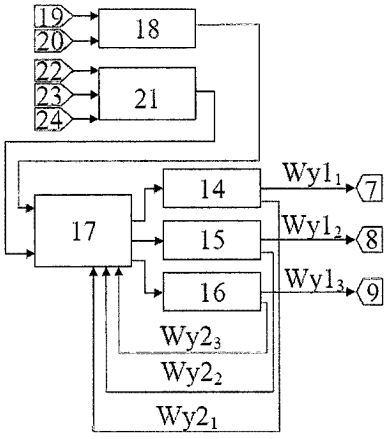


fig. 4

(57) Abstract: The solution, in accordance with the invention, consisting in at least four electromagnets symmetrically positioned inside the cylindrical casing and the electromagnetic core, is made of a set of sheets with a ring shape with internal pole shoes or the shape of integrated or separated horseshoes, however coil winding of each electromagnet is uniformly positioned on two neighbouring pole shoes of the core with the shape of a ring or on both pole shoes of horseshoes and coiled so as the pole shoes of neighbouring electromagnets has opposite polarisation and characterised by the fact that it includes three electromagnets (2,3,4) symmetrically positioned at the edge inside the cylindrical casing (5) with the core (6) of the known ring shape with pole shoes or integrated or separated horseshoes and coils(7,8,9) wound in a familiar manner. Core pole shoes 6, in the shape of a ring, from the side of horseshoes and the axis Z are equipped with rounded projections IfJ positioned symmetrically to the axis d of a pole shoe. In the frontal surface of one of core pole shoes 6, of each electromagnet 2,3,4 there are positioned recesses H, however, on the opposite side - internal edges of electromagnetic pole shoes 2,3,4 are tangential to arc with a adequately adjusted radius. Moreover, the core 6 of each electromagnet (2,3,4) is equipped with mounting holes 12 and the stabilising inlet 13, electromagnets (2,3,4) in the casing (5).

WO 2011/074996 A2

Active magnetic bearing and control system for active magnetic bearing

The subject of the invention is an active magnetic bearing and the control system of an active magnetic bearing which may be applied for bearing mounting of shafts within various engines and machines.

The already known active magnetic bearing for mounting bearings on drive shafts is made of four actuators in a form of electromagnets, positioned symmetrically within the circuit, inside the cylindrical casing, which are made of a core with a wound coil. The electromagnet cores, making the bearing stator, are made of a set of ring-shaped sheets with internal straight teeth or integrated or separated horseshoes with endings in form of straight teeth, constituting pole shoes of the electromagnet. The coils are wound uniformly, adequately on two ring-shaped neighbouring pole shoes of the core or both pole shoes of each horseshoe in such a manner that the pole shoes of the core are magnetically polarised against each other.

The known control system of an active magnetic bearing consists of current meter circuits in form of measurement shunts which are mounted in series with bearing electromagnet coils, connected to the power controller. Outputs of meter circuit systems are connected, by means of filters, with inputs of the comparator whose output is connected with the input of the power controller.

The bearing, in accordance with the invention, encompasses at

least, four magnets positioned symmetrically inside the cylindrical casing, and the electromagnetic core is made of a set of ring-shaped sheets with internal pole shoes or has a shape of integrated or separated horseshoes, however, the coils of each electromagnet are uniformly positioned on neighbouring pole shoes of the ring-shaped core or on both horseshoe-shaped pole shoes and coiled so as the pole shoes of the neighbouring electromagnets have opposite polarisation characterised by three electromagnets situated within the circuit, inside the cylindrical casing, with the ring – shaped core along with pole shoes or integrated or separated horseshoes and coils wound in the familiar manner. Ring-shaped pole shoes of the core and horseshoes from the roll axis of the active magnetic bearing are equipped with rounded projections situated symmetrically to the axis of pole shoes, and on the frontal surface of one of the core pole shoes of each electromagnet there is a recess, though from the opposite side, internal edges of core electromagnet pole shoes are tangential to the arc with an adequately selected radius. Moreover, the core of each electromagnet is equipped with mounting holes and an inlet stabilizing electromagnets in the casing.

The circuit, in accordance with the invention, encompasses at least four electromagnets and a power controller, which is characterised by the fact that coils of three electromagnets are connected adequately with first outputs separated from power controllers that are directly connected with regulator outputs. Regulator outputs are adequately connected through the shaft position block to two sensors of shaft position which are mounted in the bearing casing holes, however, through the magnetic field induction detector block, there are three sensors of magnetic induction connected, which are positioned in the recesses of electromagnet pole shoes as well as the second output of power controllers.

Moreover, each power controller has an H type transistorised bridge, connected adequately with terminals of the first output of a given power controller and by a current load meter circuit along with the second power

controller. One type H bridge output is connected with the known source of direct voltage and the second controlling input through a part of logics and voltage generator with the external circuit, which is connected with a comparator output. However, one comparator input is connected with the regulator output; the second comparator input is connected with the current load meter circuit output.

Active magnetic bearing, in accordance with the invention, thanks to the application of three electromagnets as well as a position of magnetic field induction sensors in the frontal pole shoe recesses of its electromagnets allows for narrowing the gap of a magnetic circuit and in consequence it allows to increase the rigidity of the bearing and electromagnetic forces, increase in the quality of control as well as decrease in the size of the bearing.

The subject of the invention is depicted as an example of manufacturing in fig. 1 that presents the transverse section of the structure of the active magnetic bearing, fig. 2 - longitudinal section along the line A-A, fig. 3 - transverse section of another version of the bearing, fig. 4 - block diagram of bearing control system and fig. 5 - block diagram of the power controller.

The bearing, in accordance with the invention, assigned for mounting bearings on a shaft 1, has three symmetrical electromagnets 2,3,4 positioned at the inside edge of the cylindrical casing 5 with the core 6 made of the set of electro technical ring – shaped sheets with internal pole shoes or integrated or separated horseshoes and coils 7, 8, 9. Winding of coils 7, 8, 9 for each electromagnet 2, 3, 4 is uniformly positioned on two neighbouring pole shoes of the ring-shaped core 6 or on both horseshoes shaped pole shoes and coiled so as the pole shoes of the neighbouring electromagnets have opposite polarisation. Core pole shoes 6, regardless of its shape, from the side of the axis Z of the active magnetic bearing are equipped with rounded projections 10 situated symmetrically to the axis d of a pole shoe. Moreover, in the frontal surface of one of the pole shoes of each of electromagnet 2,3,4 there are positioned recesses 11, however,

on the opposite side internal edges of electromagnetic pole shoes 2, 3, 4 tangential to arc with a adequately adjusted radius. The core 6 of each electromagnet 2, 3, 4 is equipped with mounting holes 12 and the stabilising inlet 13, allowing for mounting and stabilisation of electromagnets within the casing 5.

The bearing, in accordance with the invention, consists of three power controllers 14,15,16 mounted longitudinally to the source of direct voltage not indicated in the figure. First outputs $Wy1_1$, $Wy1_2$,$Wy1_3$ of power controllers 14, 15, 16 are adequately connected with coils 7, 8, 9 of three electromagnets 2, 3, 4 of the active magnetic bearing, in accordance with the invention, and inputs of these power controllers 14, 15, 16 are connected with separate regulator outputs 17. One of the regulator outputs 17 is connected adequately through the position block of the bearing mounting shaft 1 with two contactless position sensors 19, 20 of shaft 1, which are mounted in the casing holes 5 perpendicular towards each other axes X,Y lying on the parallel surface to the frontal surface of the core 6 of bearing electromagnets 2, 3, 4. Another regulator inputs 17 are connected through the magnetic field induction detector block 21 to three induction sensors 22, 23, 24 which are positioned in electromagnet 2,3,4, pole shoe recesses 11 and to subsequent inputs of the regulator 17 there are connected second outputs $Wy2_1$, $Wy2_2$, $Wy2_3$ power controllers 14, 15, 16. Each power controller 14,15,16 has a bridge H type 25 with DMOS transistors connected adequately with terminals of the first input $Wy1_1$, $Wy1_2$, $Wy1_3$ of the power controller 14, 15, 16 and through the meter circuit of current load 26 with the second output $Wy2_1$, $Wy2_2$, $Wy2_3$ power controller 14, 15, 16, and one bridge output type H connected with, not seen in the figure, the known source of direct voltage and the second controlling input controlling the bridge H type 25 through the part of logics 27 and voltage generator 28 of regulated frequency with the connected external capacity and resistance circuit 29 connected with a comparator output 30, whose one input is connected with the regulator output 17, second, though, connected with the current load meter circuit output circuit

26. As contactless position sensors 19, 20 of the bearing shaft 1, there were applied eddy-current or laser sensors.

The operation of the circuit, in accordance with the invention, is as follows. Active magnetic bearing, in accordance with the invention, using the phenomenon of levitation, causes the hold of the shaft 1 in the bearing space with a radius of R_b, limited by pole shoes of three independent electromagnets 2, 3, 4, which are positioned towards each other at the angle of 120^c and in this position that shaft 1 axis lies in the bearing of axis Z or makes an acute angle depending on the needs. Measurement signals from two eddy-current position sensors 19, 20, needed for contactless measurement of distance between the shaft and 1 and pole shoes of particular electromagnets 2, 3, 4 and signals from three magnetic field induction sensors 22, 23, 24 positioned in recesses 11 of electromagnet pole shoes 2, 3, 4 are processed adequately in the block of the position 18 and in induction detector block 21 on voltage signals proportionally to measured values. Then, on the basis of the gained signals from position block inputs 18 and induction detector block 21 and voltage signals proportional to measured load currents for particular electromagnets 2,3,4 gained from the second outputs $Wy2_1$, $Wy2_2$, $Wy2_3$ of power controllers 14, 15, 16, there are made, by means of the regulator 17, signals of the given currents for particular power controllers 14, 15, 16. The signals of operating current from the regulator 17 are compared with adequate power controllers 14, 15, 16 with their adequate signals of real current that goes through coils 7,8,9 of electromagnets 2,3,4 through comparators 30, whose output signals cause generating signals with the course of a saw shape on generator voltage outputs 28 of changeable frequency. The obtained signals control, through parts of logics 27 and working DMOS transistors H type 25, power controls 14,15,16 are supplied from the invisible in the figure, sources of direct voltage of given current efficiency and voltage chosen to the parameters of the powered coil windings 7,8,9 , electromagnets 2,3,4 and the mechanical structure of the bearing. Direct voltage of current source for electromagnets 2, 3, 4 of

the bearing is broken by bridge transistors H type 25 of controllers 14, 15, 16 with changeable frequency, and the current gained on their input going in coils 7,8,9 electromagnets 2,3,4 has a saw-shaped course of the required amplitude and variable duty cycle.

Patent claims

1. Active magnetic bearing consisting in at least four electromagnets symmetrically positioned on the cylindrical casing and the core of the electromagnets is made of a ring-shaped set of sheets with internal pole shoes or in form of integrated or separated horseshoes while coil winding of each electromagnet is adequately positioned on two neighbouring pole shoes of the ring – shaped core or on both horseshoe pole shoes and are so wound as the pole shoes of neighbouring electromagnets have opposite polarisation characterised in that they include three electromagnets (2,3,4) symmetrically positioned on the edge inside the cylindrical casing(5) with the core (6) in the known ring-shape with pole shoes or integrated or separated horseshoes and coils (7,8,9) wound in the known manner and the pole shoes of the core (6) in the shape of a ring and horseshoes from the side of the axis (Z) of the active magnetic bearing and equipped with rounded projections (10) positioned symmetrically in relation to the axis (d) of pole shoes, moreover on the frontal surface one of core (6) pole shoes of each electromagnet (2,3,4) there is a recess (11) ,however, from the opposite side internal edges of pole shoes of the core (6) of electromagnets (2,3,4) are tangential to the arc with a adequately radius, moreover the core (6) of each electromagnet (2,3,4) is equipped with mounting holes (12) and stabilising inlet (13) electromagnets (2,3,4) in the casing (5).

2. The control system of active magnetic bearing consists in at least four electromagnets and a power controller characterised in that the coils (7,8,9) of three electromagnets (2,3,4) which are adequately connected with the first outputs ($Wy1_1$, $Wy1_2$, $Wy1_3$) separate power controllers (14,15,16), whose inputs are connected adequately with regulator outputs (17), and regulator inputs (17) that are connected

adequately through the position block (18) of the shaft (1) two position sensors (19, 20) of the shaft (1) mounted in casing holes of the bearing (5) and through detector block (21) of magnetic field induction three induction sensors (22,23,24) positioned in recesses (11) of electromagnet pole shoes (2,3,4) and second outputs ($Wy2_1$, $Wy2_2$, $Wy2_3$) of power controllers (14,15,16).

3. The system, in accordance with the claim 2, is characterised in that each power controller (14,15,16) consists in the H type transistorised bridge (25) connected adequately with terminals of the first output (Wy1) of the power controller (14,15,16) and through the current load measurement circuit (26) with the second output (Wy2) of the power controller (14,15,16) and one H type bridge input (25) connected with the known source of direct voltage, the second of its input controlling by the part of logics (27) and voltage generator (28) with installed external circuit (29) is connected with the output of comparator (30) whose one input is connected with the regulator output of the current load measurement circuit (26).

"Active magnetic bearing and control system
of active magnetic bearing"

List of numbers in the figure

1 –shaft

2,3,4 – electromagnets

5 – bearing casing

6 – electromagnet core

7,8,9 – electromagnet coils

10 – projections

11 – recess

12 – mounting holes

13 – stabilising inlet

14,15,16 – power controllers

17 – regulator

18 – shaft position block

19, 20 – shaft position sensors

21 – magnetic field induction detector block

22,23,24 – magnetic field induction sensors

25 – H type transistorised bridge

26 – current load measurement circuit

27 – part of logics

28 – voltage generator

29 – external generator circuit

30 – comparator

X, Y – axes of casing holes

Z – axis of active magnetic bearing

d - symmetry axis of pole shoe

Rb – internal radius of the bearing

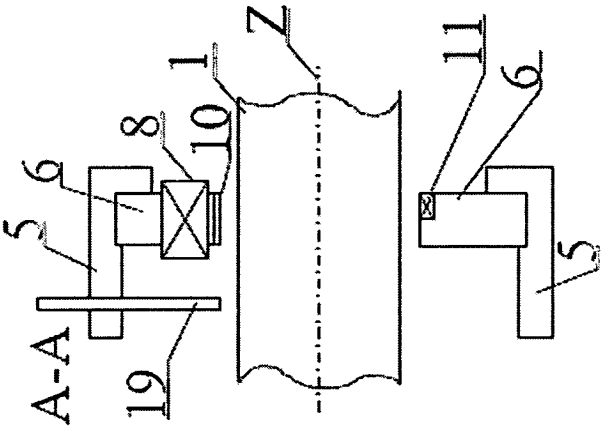


fig. 2

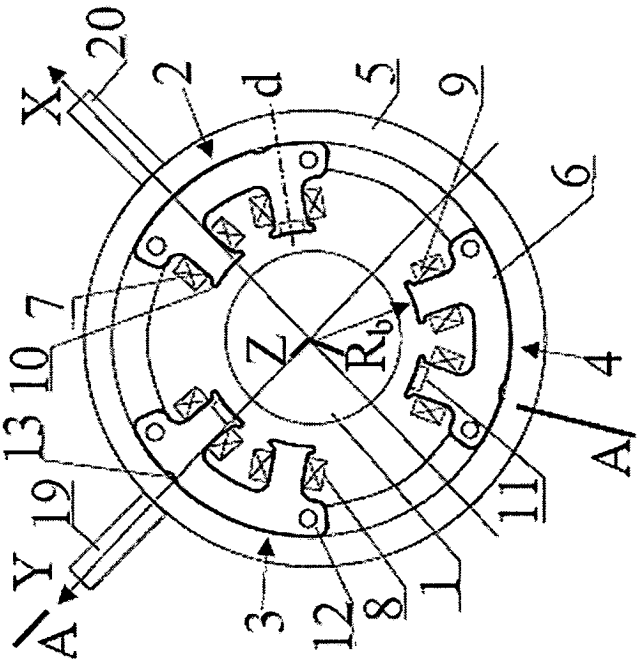


fig. 1

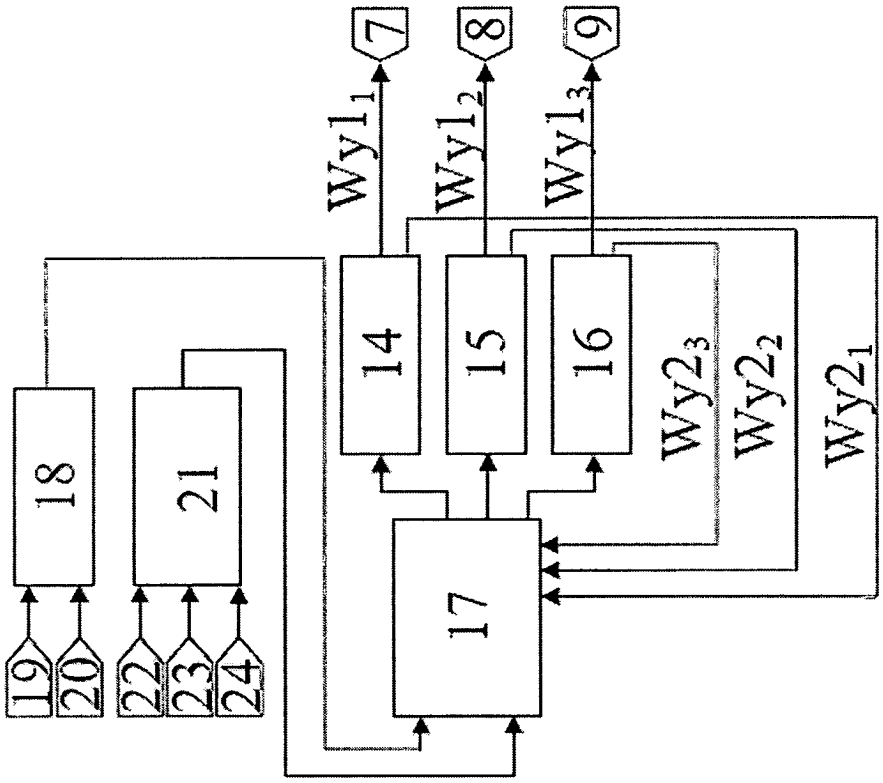
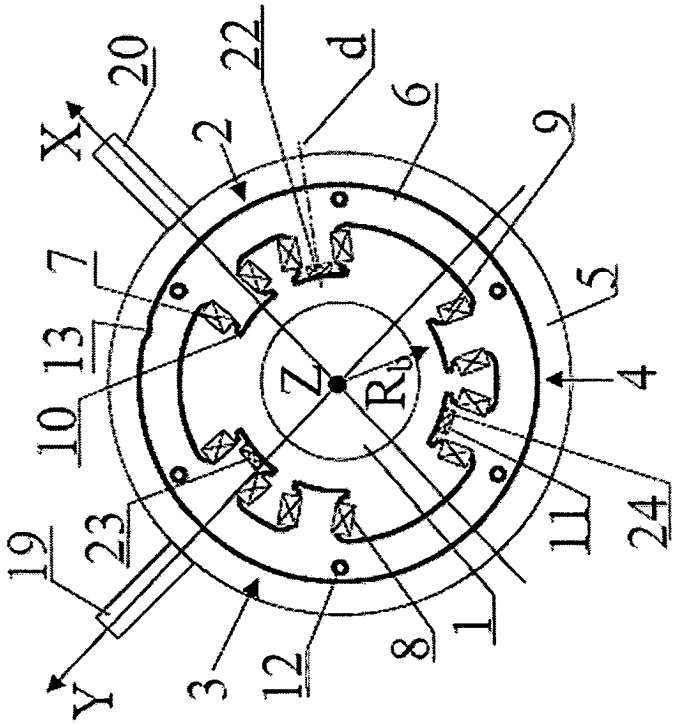

Wy1₁
Wy1₂
Wy1₃
7
8
9
14
15
16
Wy2₃
Wy2₂
Wy2₁
18
21
17
19
20
22
23
24

fig. 4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d
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fig. 3

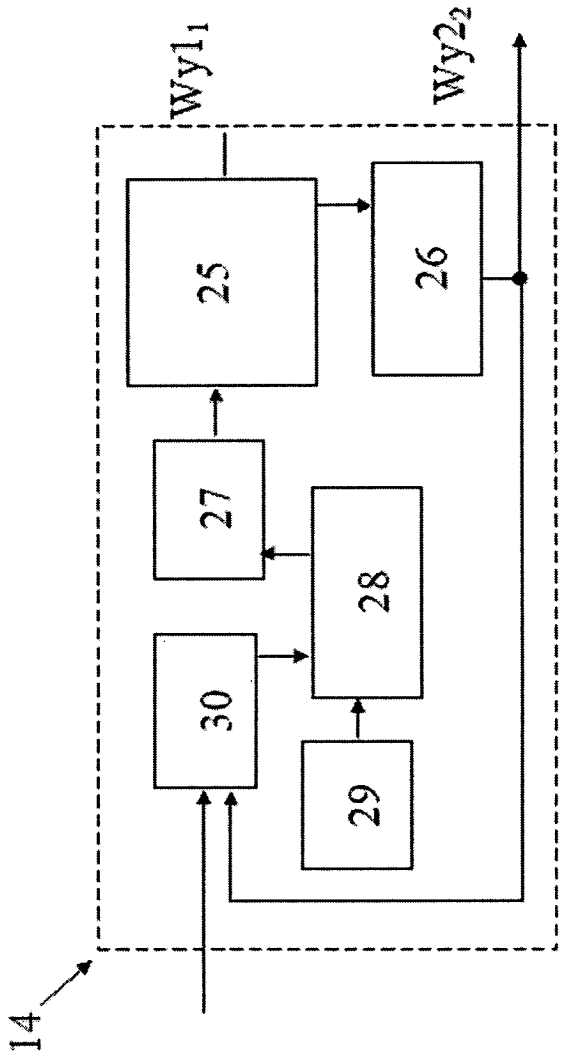

fig. 5