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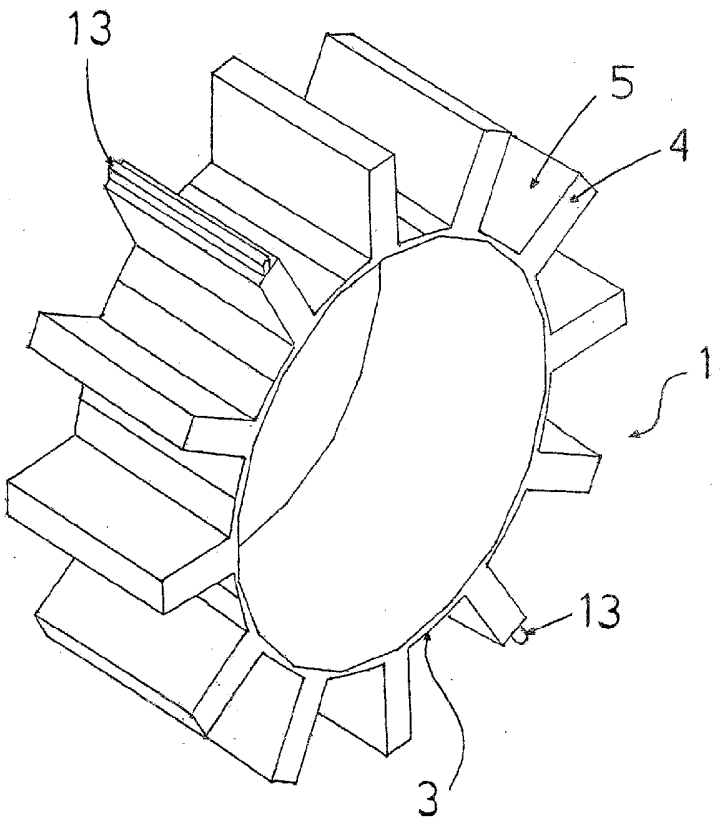
(54) Title: ELECTRIC MOTOR WITH IMPROVED CONNECTION DEVICE




(57) Abstract: Described herein is an electric motor comprising: a stator unit having at least one first shaped body, which is made of magnetic material and has a plurality of teeth interspersed with respect to one another by slots, and phase windings, which comprise a plurality of coils arranged on said first shaped body; and connection means, which are designed to connect electrically the phase windings to an electrical-supply source of the motor. Said connection means comprise a plurality of connection terminals connected to said coils, a shaped body made of electrically insulating material, and a plurality of electrically conductive shaped elements, said electrically conductive shaped elements having first and second means for coupling, respectively, with said insulating shaped body and with said connection terminals, said electrically conductive shaped elements being positioned with respect to one another and arranged so that they are coupled to the insulating shaped body and to the connection terminals in order to define connection paths between the coils of one and the same phase and between the phase windings and said supply source according to pre-defined paths.

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# ELECTRIC MOTOR WITH IMPROVED CONNECTION DEVICE

## DESCRIPTION

The present invention relates to an electric motor, in particular a servo-motor of a brushless type, having an improved electrical-connection device, as well as optimized structure and overall characteristics.

As is known, electric motors are devices that, thanks to their good performance in particular in terms of versatility, reliability and duration over time, find an increasingly widespread application in innumerable industrial sectors, such as for example in robotized plants, in the automotive sector in general, for movement of machinery and/or tools in textile plants, in the foodstuff industry, in plants for the production of paper, ceramics, plastic, glass, as well as many others.

Said massive diffusion has led to the development of a wide range of different types of motors to be offered to the market, all of which are characterized by the common need to provide solutions with higher performance and higher functional efficiency, which can be produced at reduced costs and in lots as large as possible. A typical class of electric motors is represented, for example, by the so-called brushless motors, which comprise, in their basic components, a rotor provided with one or more permanent magnets, and a stator, mounted on which are the phase windings which are to be connected to a supply source.

In the current state of the art, although the electric motors available on the market adequately meet the functions and applications for which they are designed, they still present some aspects that can be improved, in particular as regards their construction in terms of structural layout as a whole, as well as in terms of their individual components, as regards the choice and amount of materials for their production, as regards the construction and configuration of the windings, and as regards the operative connection thereof to one another and to the supply source. For example, the production of the stator often involves recourse to quite problematical operations and to constructional structures characterized by a non-optimal use of the amount and type of material used. Said drawbacks are even more evident and significant in the production and assembly of the phase windings, which more often than not involve recourse to sophisticated machinery and long and laborious operations, in some cases even with manual intervention. Particularly complicated is the step of connection between the coils of each phase and between the phases and the supply source of the motor. In fact, the connection is usually obtained by means of systems that are complicated both as regards their structure and as regards their practical use, which lead, for example, to intertwined paths, with

conductive elements that may even be set on top of one another, and consequent problems in terms of overheating, problems of reliability, need for particular insulation, etc. Finally, the widespread choice of windings in a distributed configuration, whether they are set overlapping or concentric, leads to a consumption of an excessive amount of useful conductive material with an unsatisfactory factor of filling of the stator slots and considerable encumbrance.

The main task of the present invention is to provide an electric motor which is able to overcome the drawbacks mentioned above, and in particular which, as compared to known solutions, can be manufactured in an economically optimized way, enables a simplified assembly and provides at the same time functional performance of a high standard and with high reliability.

The above task is achieved by an electric motor comprising:

- a stator unit having at least one first shaped body, which is made of magnetic material and has a plurality of teeth interspersed with respect to one another by slots, and phase windings, which comprise a plurality of coils arranged on said first shaped body; and
- connection means designed to connect electrically the phase windings to an electrical-supply source of the motor; said motor being characterized in that said connection means comprise a plurality of connection terminals connected to said coils, a shaped body made of electrically insulating material, and a plurality of electrically conductive shaped elements, said electrically conductive shaped elements having first and second means for coupling, respectively, with said insulating shaped body and with said connection terminals, said electrically conductive shaped elements being positioned with respect to one another and arranged so that they are coupled to the insulating shaped body and to the connection terminals in order to define connection paths between the coils of one and the same phase and between the phase windings and said supply source according to pre-defined paths.

Further characteristics and advantages of the invention will emerge more clearly from the description of preferred but non-exclusive embodiments of the electric motor according to the invention, illustrated purely by way of non-limiting example in the annexed plate of drawings, in which:

figures 1 and 2 are perspective views illustrating two components of the stator unit used in the electric motor according to the invention;

figure 3 is a perspective view illustrating a component of a coil to be used in the fabrication of the phase windings of the electric motor according to the invention;

figure 4 is a perspective view illustrating the elements of Figures 1 and 2 assembled

together and with the coils of the phase windings;

figure 5 is a perspective view illustrating a device for connection of the phase windings to a supply source;

figure 6 is a top plan view illustrating the electrically conductive components of the connection device of figure 5.

With reference to the above figures, the electric motor according to the invention comprises a stator unit having at least one first shaped body, designated in figure 1 by the reference number 1. Preferably, the stator unit is formed by a first shaped body 1 and a second shaped body 2 illustrated in figure 2. The two shaped bodies 1 and 2, which are both made of appropriate magnetic material, are structurally separate and are configured so as to be operatively fitted together according to the modalities that will emerge from the ensuing description. In particular, the second body 2 is ring-shaped, and is preferably made of a first composite magnetic material comprising electrically insulated soft ferromagnetic particles, i.e., a magnetic material of the SMC (Soft Magnetic Composites) type, for example Somaloy®. In turn, the first body 1 has a shape complementary to that of the first body 2, which, in the example of embodiment illustrated in the figures, is also ring-shaped. In particular, the body 1 has a jumper 3, which delimits the internal surface of the body itself and from the outer surface of which there radially extends a plurality of teeth 4 interspersed with respect to one another by slots 5. Advantageously, on the teeth 4 and in the corresponding slots 5 the phase windings 6 are arranged in a concentrated configuration, as is for example illustrated in figure 4. By the expression "windings arranged in a concentrated configuration" is to be understood that each individual coil of a phase winding is arranged around and embraces just one tooth 4. Preferably, the shaped body 1 is made using a second magnetic material that is different from the magnetic material of which the shaped body 2 is made. Advantageously, in the embodiment of the electric motor according to the invention, the shaped body 1 is obtained using a pack of magnetic laminations.

According to a particularly preferred embodiment, the phase windings are made by means of a plurality of individual coils 6 constituted, in their essential components, by prefabricated modules that are each fitted around a respective tooth 4. In particular, according to a first configuration of embodiment, fitted around each tooth 4 of the stator is a corresponding coil 6, or alternatively, the coils 6 are fitted around the teeth 4 in an alternating way, i.e., around every other tooth. In this way, windings are obtained in a concentrated configuration, which may be either a double-layer one or a single-layer one. By the expression

"single-layer configuration" is to be understood that in each individual slot 5 there is only one output (or input) side of a coil 6, whereas by the expression "double-layer configuration" is to be understood that in each individual slot 5 there are the output (or input) sides of two different coils. The above choices enable optimization of the amount of material used according to the dimensions of the motor.

The prefabricated coils 6 comprise a bobbin 7, made of electrically insulating material, for example a plastic material with high dielectric and mechanical characteristics, e.g., PPS (polyphenylene sulphide), PPA (polyphthalamide), or Stanyl®, around which is wound an electrical conductor 8, for example an electric wire or a flat cable, which can have a cross section that may be circular, or rectangular, or of some other shape, so as to optimize the filling factor of the slots 5.

As illustrated in detail in figure 3, each bobbin 7 comprises a shaped body, for example shaped like an H, having a through opening 9 designed to house a corresponding tooth 4 and at least one housing seat 10, preferably two seats 10, which, as illustrated in figures 3 and 4, develop in a transverse direction with respect to the through opening 9.

The electric motor according to the invention further comprises connection means designed to connect electrically the phase windings to an electrical-supply source of the motor itself.

Advantageously, said connection means comprise a plurality of connection terminals 11 and an appropriate connection device, designated as a whole by the reference number 100 in figure 5. Preferably, the connection device 100 comprises a shaped body 101, which is made of electrically insulating material, and a plurality of electrically conductive shaped elements 102, which comprise first and second means for coupling, respectively, with the insulating shaped body 101 and with the connection terminals 11. In particular, the electrically conductive shaped elements 102 are positioned with respect to one another and arranged so that they are coupled to the insulating shaped body 101 and to the connection terminals 11, in order to define connection paths between the coils 6 of one and the same phase and between the phase windings and a supply source according to pre-defined paths.

As illustrated in greater detail in figure 5, preferably, the shaped elements 102 are arranged with respect to one another and fitted to the insulating shaped body 101 so as to lie substantially in one and the same plane.

In the embodiment illustrated, the connection terminals 11 are made via substantially rigid small pins made of electrically conductive material, and are connected to the coils 6 so as

to project transversely therefrom and define a plurality of coplanar surfaces for electrical coupling with the conductive elements 102. In particular, the terminals 11, preferably two for each coil 6, are press fitted within corresponding seats 10, and are then each connected to one end of the corresponding electrical conductor 8.

In turn, the shaped body 101 is preferably made of a single piece, also in this case, for example, using Stanyl®, PPS, PPA, or in any case any other material provided that it is compatible with the application, which has a reticulated structure with open windows 109, and provides the device 100 with the necessary characteristics of support and mechanical strength. In addition, the body 101 comprises at least one protective rim 106, preferably two rims 106 as illustrated in figure 5, which develop in a transverse direction with respect to the plane of lie of the plurality of shaped elements 102, so as to provide a barrier for protection of the electrically active stator parts from parts at a different potential, for example the body of the motor. Finally, the shaped body 101 preferably comprises a dedicated area designed for coupling with additional components. In particular, said dedicated area comprises for example a radial protuberance designated as a whole in figure 6 by the reference number 107, on which an electrical/electronic circuit 108 is defined, which comprises for example a printed-circuit board (PCB) and/or one or more microchips designed for coupling for example with sensors, or other additional components, for example devices for temperature measurement or for thermal protection.

As illustrated in figure 6, the shaped elements 102 are preferably made in structurally separated pieces and are coupled mechanically, preferably by snap-action, with the insulating body 101 in an way that is extremely simple and effective at the same time. In particular, the first coupling means comprise through openings 104 that receive corresponding protuberances 105 defined on the insulating shaped body 101, whilst the second coupling means comprise seats 103 each designed to receive a corresponding connection terminal 11.

Alternatively, the conductive elements 102 and the insulating body 101 can be made directly of a single co-moulded piece.

In practice, the second shaped body 2, once assembled with the coils mounted around the teeth 4 and connected to one another via the device 100 and the terminals 11, is operatively coupled to the first shaped body 1, by being inserted inside the latter. Preferably, the two shaped bodies 1 and 2 are operatively fitted together by means of a mechanical coupling with play, according to an embodiment that is simple as regards assembly. Preferably, at least one of

the two bodies 1 and 2 can be provided with coupling means designed to favour their mutual positioning in a desired configuration. Said mutual-coupling means can be provided on both of the bodies and comprise, for example, one or more grooves 12 defined on the first body 1 and one or more corresponding projections 13 provided on the second body 2, as illustrated schematically in figures 1 and 2, and are configured so as to enable proper centring between the two bodies and prevent their relative rotation.

In addition, advantageously, envisaged in the motor according to the invention is the use of a casting of electrically insulating material, for example an electrically insulating epoxy resin with high thermal conductivity, e.g., of the ULTIFIL type, or in any case another commercially available resin, which envelops at least partially, and preferably completely, the coupled parts. Preferably, casting is performed in vacuum conditions around the stator unit so as to envelop it at least partially and eliminate any possible cavities that would otherwise damage the insulation system. In this way, a coating-filling layer is obtained, designated as a whole by the reference number 14 in figure 4, which bestows mechanical consistency upon the entire stator unit as well as upon the individual coils so as to form a single, compact and mechanically sturdy block, which guarantees an insulation system that is practically free from partial electrical discharges and moreover helps to dissipate the heat that is generated during operation of the motor, thus contributing to improving its overall performance.

Finally, in the assembly stage, the rigid terminals are in a pre-defined position and substantially in one and the same plane ready for coupling with the device 100, which in turn, thanks to its very configuration, can be directly fitted into place with a single simple operation by inserting the terminals 11 into their respective seats 103. The terminals 11 are then connected to the elements 102 via press fits, for example by means of appropriate connectors, or else via welding. Among other things, the shape of the insulating body 101 on the one hand enables coating and protection of just the necessary parts, namely, the surfaces of the conductive elements 102, and on the other hand favours, via the openings 109, passage of insulating material, for example a casting of resin, thus enabling a decidedly optimal coating-filling of insulating material, where necessary, and optimal heat dissipation thanks to the thermally conductive characteristics of the resin.

It has, in practice, been noted how the electric motor according to the invention, thanks to the innovative structure and functionality of its parts, and in particular of the connection means, fully performs the pre-set task, providing a series of advantages as compared to the known art. In fact, in addition to what has been mentioned above, on the one hand the

ensemble formed by the connection device 100 and the terminals 11 enables considerable simplification in the step of assembly of the connections between the coils of each phase, and between the phase windings thus made and a supply source, thanks in particular to the fact that the connections are made in a single plane without any intertwining or overlapping. On the other hand, the production costs are considerably reduced, by virtue of the structural simplicity and functional effectiveness of the components 101 and 102, especially if compared, for instance, with manual-assembly solutions or solutions which use PCBs. In addition, the motor as a whole presents a structure of a modular type, assembly of which is extremely simplified as compared to more conventional solutions. A significant improvement is represented by the provision of the coils as individual prefabricated modules, which are then mounted directly each around the respective tooth with a simple mechanical operation of mere positioning. In addition, the coils themselves are suited, by virtue of their modularity, to creating motors of different sizes with significant advantages from the standpoint of flexibility of application, and with economic benefits from the standpoint of production. The specific choice of the materials for its production, namely, the choice and combination of two different magnetic materials for the bodies 1 and 2, and of the particular layout of the windings, enable further substantial benefits. In particular, provision of the body 2 using magnetic laminations enables a structure to be obtained that is optimized as regards dimensions and that is at the same time mechanically robust, stable and capable of achieving higher levels of magnetic saturation, so as to require a smaller amount of material for its production. In turn, by making the body 1 of an SMC material, enables an element of a single piece to be made, which is solid and presents low losses at high frequencies, thus enabling motors with a higher number of poles to be obtained given the same amount of material, or else the necessary amount of material to be decreased given the same number of poles. Finally, arrangement of the windings in a concentrated configuration enables a drastic reduction in the amount of conductive material used as compared to the solution with distributed windings.

The solution according to the present invention presents a structure that makes it possible to provide different types of motors, but is particularly suited for implementation and use as a servo-motor of a brushless type.

The electric motor thus conceived may undergo numerous modifications and variations, all falling within the scope of the inventive idea. In addition, all the items may be replaced by other technically equivalent elements. For example, the bodies 1 and 2 could have a differently shaped annular conformation, for example a quadrangular one, a square cross-shaped one, or

one with any other shape provided that it is compatible with the application. The body 1 and/or the body 2 could be made of a number of separate pieces mechanically fitted to one another, in order to increase the modularity of the motor. The means for mechanical coupling between them could be provided only on the body 1 (or only on the body 2) and could have a different configuration, as likewise the conductive elements 102 and/or the insulating body 101, etc. In addition, the protuberance 107 of the body 100 could extend towards the inside of the device 100. In practice, the type of materials adopted for the applications envisaged as described above, as well as the dimensions, may be any whatsoever according to the requirements and the state of the art.

CLAIMS

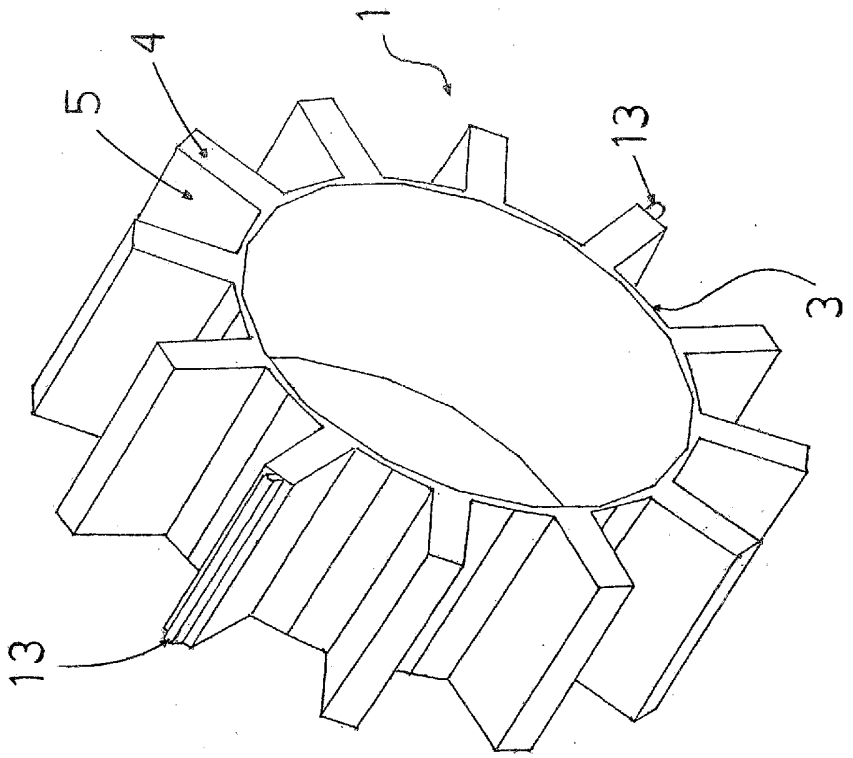
1. An electric motor comprising:
   - a stator unit having at least one first shaped body, which is made of magnetic material and has a plurality of teeth interspersed with respect to one another by slots, and phase windings, which comprise a plurality of coils arranged on said first shaped body; and
   - connection means designed to connect electrically the phase windings to an electrical-supply source of the motor;

   said motor being characterized in that said connection means comprise a plurality of connection terminals connected to said coils, a shaped body made of electrically insulating material, and a plurality of electrically conductive shaped elements, said electrically conductive shaped elements having first and second means for coupling, respectively, with said insulating shaped body and with said connection terminals, said electrically conductive shaped elements being positioned with respect to one another and arranged so that they are coupled to the insulating shaped body and to the connection terminals in order to define connection paths between the coils of one and the same phase and between the phase windings and said supply source according to pre-defined paths.
2. The electric motor according to claim 1, characterized in that said electrically conductive shaped elements are positioned with respect to one another and coupled to said insulating shaped body so as to lie substantially in one and the same plane.
3. The electric motor according to claim 1 or claim 2, characterized in that said plurality of electrically conductive shaped elements are coupled by snap-action to said insulating shaped body.
4. The electric motor according to one or more of the preceding claims, characterized in that said first coupling means comprise seats each designed to receive a corresponding connection terminal, and said second coupling means comprise through openings designed to receive corresponding protuberances defined on the insulating shaped body.
5. The electric motor according to one or more of the preceding claims, characterized in that said insulating shaped body comprises a reticular structure having a plurality of openings and at least one protective rim that develops in a transverse direction with respect to the plane of lie of said plurality of electrically conductive shaped elements.

6. The electric motor according to claim 1, characterized in that said plurality of electrically conductive shaped elements and said insulating shaped body are made of a single co-moulded piece.
7. The electric motor according to one or more of the preceding claims, characterized in that said insulating shaped body comprises a shaped protuberance on which a connection circuit is provided.
8. The electric motor according to one or more of the preceding claims, characterized in that said connection terminals are made via substantially rigid small pins made of electrically conductive material.
9. The electric motor according to claim 8, characterized in that said connection terminals are connected to said coils so as to project in a transverse direction therefrom and define a plurality of coplanar surfaces for electrical coupling with the electrically conductive shaped elements.
10. The electric motor according to one or more of the preceding claims, characterized in that said coils each comprise a prefabricated module fitted directly around a corresponding tooth and having a bobbin made of insulating material, around which an electrical conductor is wound, and in that it comprises for each coil, a pair of connection terminals each connected to one end of the corresponding electrical conductor.
11. The electric motor according to one or more of the preceding claims, characterized in that said terminals are press fitted into corresponding housing seats envisaged in each bobbin.
12. The electric motor according to one or more of the preceding claims, characterized in that said stator unit comprises a first shaped body and a second shaped body operatively fitted together and made respectively by means of a first magnetic material and a second magnetic material which differ from one another.
13. The electric motor according to one or more of the preceding claims, characterized in that said first shaped body is obtained using magnetic laminations and said second shaped body is made of a composite magnetic material comprising electrically insulated soft ferromagnetic particles.
14. The electric motor one or more of the preceding claims, characterized in that said first and second shaped bodies of the stator unit are operatively fitted together by means of a mechanical coupling with play.

15. The electric motor according to one or more of the preceding claims, characterized in that it is a servo-motor of a brushless type.

Fig. 1



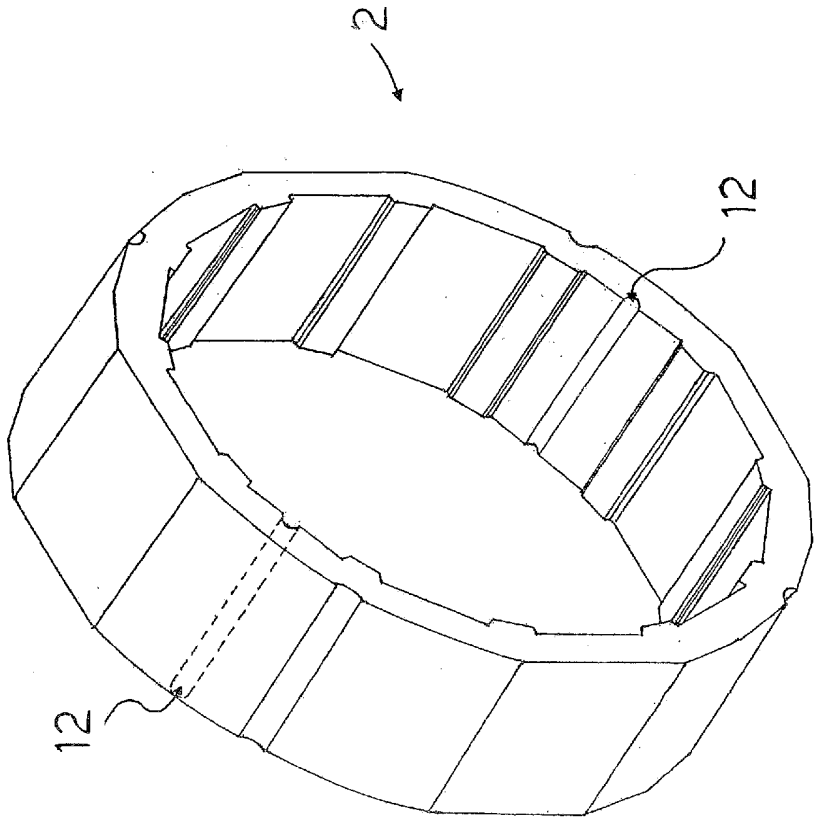




Fig. 2

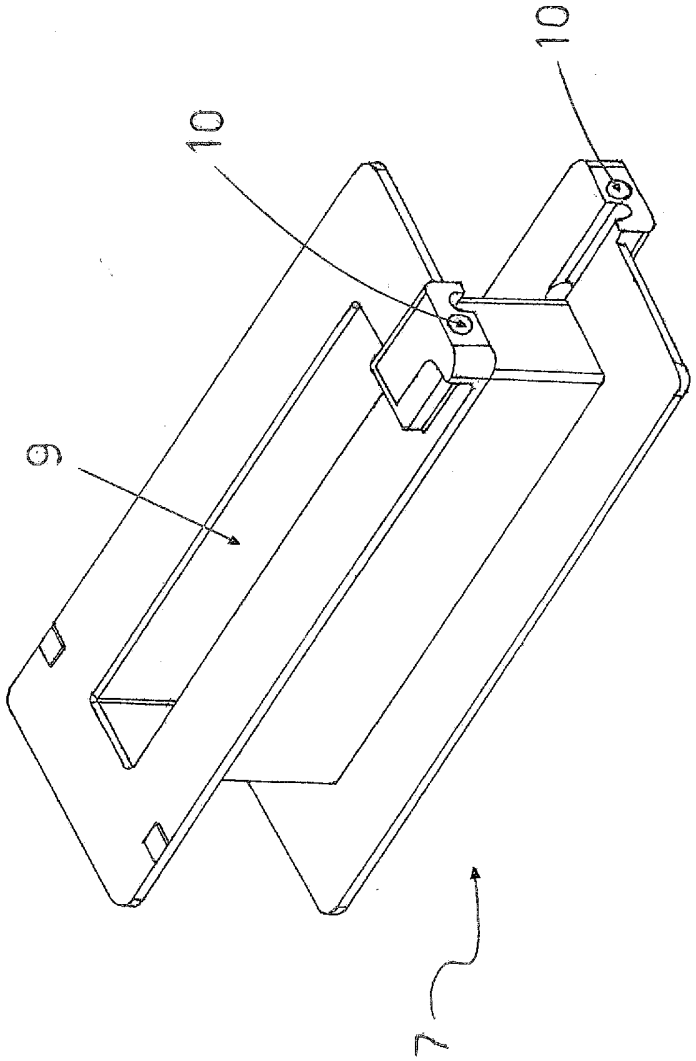



Fig 3

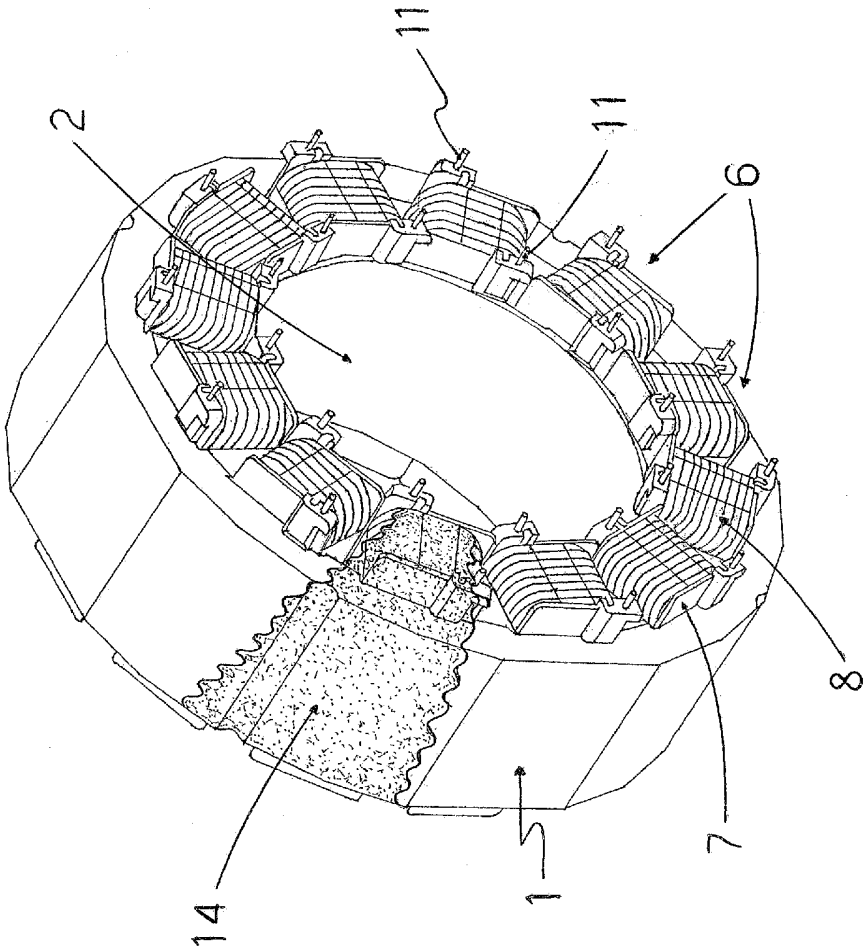



Fig.4

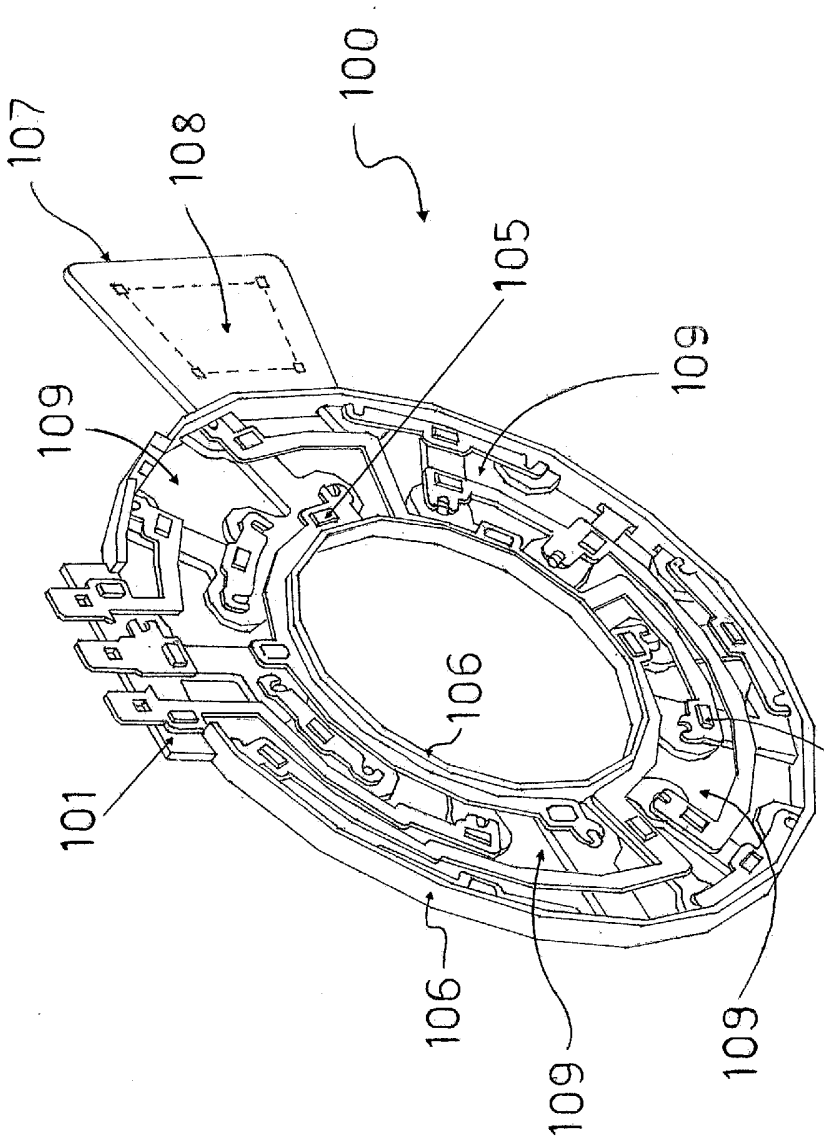



Fig. 5

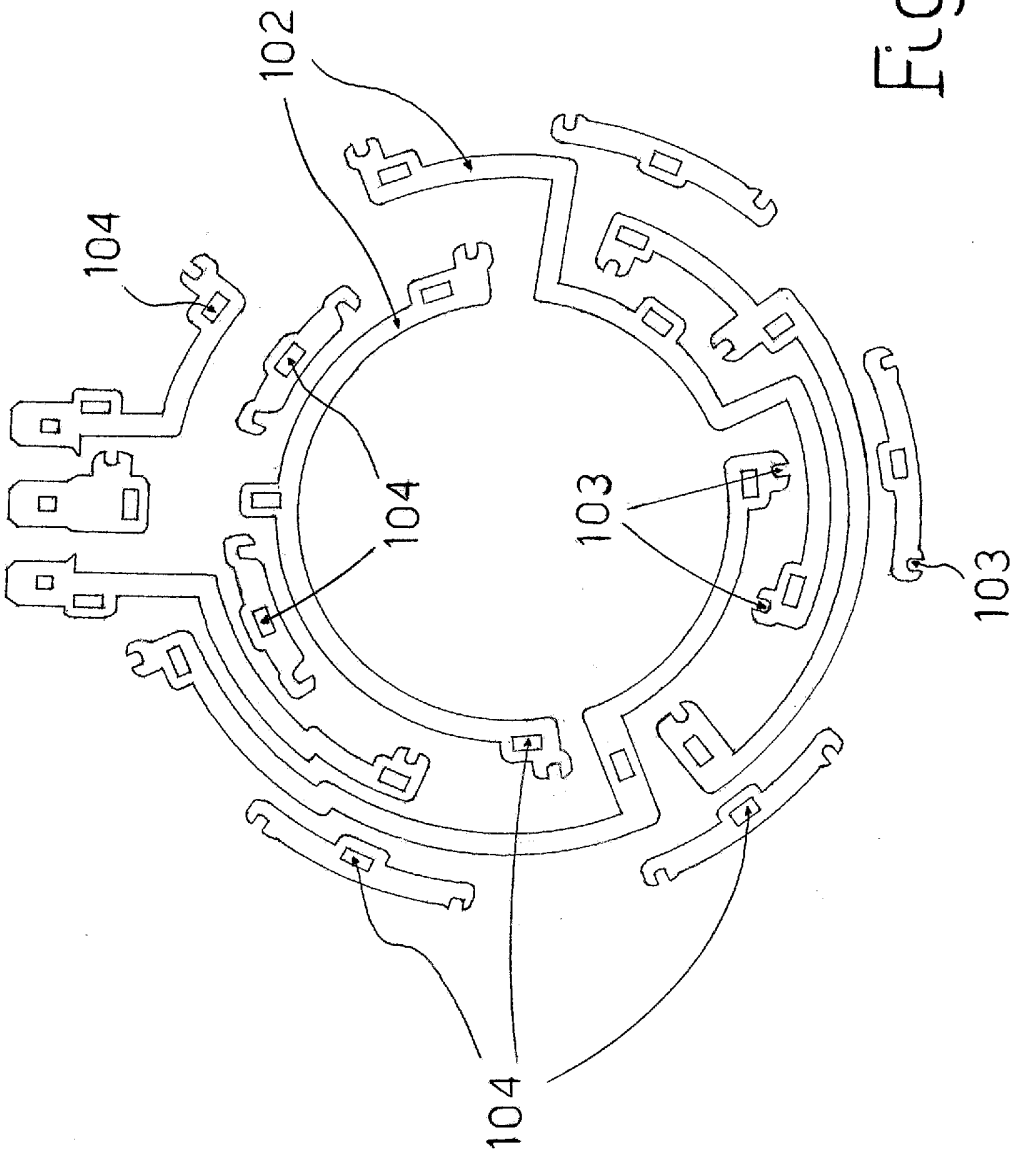



Fig. 6

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/060991

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02K3/52 H02K1/14

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02K

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 2004/114502 A (SIEMENS AKTIENGESELLSCHAFT; BOTT, ERICH; BZDZIUCH, MICHAEL; BAEHR, HUB) 29 December 2004 (2004-12-29) page 2, line 4 - page 13, line 9; figures 1-3,7,8,13,16-19 | 1-6,8-15 |
| X | PATENT ABSTRACTS OF JAPAN vol. 013, no. 136 (E-737), 5 April 1989 (1989-04-05) -& JP 63 299740 A (SHIBAURA ENG WORKS CO LTD), 7 December 1988 (1988-12-07) abstract; figures 1,3 | 1,2,4, 6-15 |
| X | WO 2004/008610 A (EMERSON ELECTRIC CO) 22 January 2004 (2004-01-22) page 5, paragraph 3 - page 7, paragraph 3; figures 1-7 | 1-6, 8-11,15 |

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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|---|---|
| 1 August 2006 | 10/08/2006 |

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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Sedlmeyer, R |

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# INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 1 322 021 A (GRUNDFOS A/S)<br>25 June 2003 (2003-06-25)<br>paragraph [0027] - paragraph [0029];<br>figures 1-3,5,7,8 | 1,2,4-6,<br>10 |

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Information on patent family members

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