ABSTRACT

In a method for production of a rotor for an electrical alternating voltage machine provided with permanent magnets a number of thin sheets are arranged in a stack (6), permanent magnets (10) are arranged in spaces formed in the stack, and a rotor body formed by the stack is stabilised by securing end sheets (7, 11) having a substantially greater thickness than said sheets on both sides of the stack. The securing of the sheets and the stack with respect to each other and at least a first end sheet (7) with respect to the stack takes place through a die casting step through introducing molten cast compound into through holes (4) extending through the sheets and by that the stack and the end sheet and against parts (8) of the front face of this end sheet while applying a high pressure.
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A rotor for an electrical alternating current machine and a method for production thereof

FIELD OF THE INVENTION AND PRIOR ART

The present invention relates to a method for producing a rotor of an electrical alternating current machine provided with permanent magnets, in which a large number of thin sheets of a material having a high magnetic permeability are fixed to each other arranged on top of each other in a stack with respect to the direction of the axis of rotation of the rotor for forming a rotor body, permanent magnets are arranged in spaces, which are formed in said stack by arranging the sheets with apertures carried out therein substantially covering each other and which are distributed around the sheets close to the periphery thereof, and the rotor body is stabilised by bracing end sheets having a substantially greater thickness than said sheets on both sides of the stack, as well as a rotor for such an electrical alternating current machine according to the preamble of the appended independent rotor claim.

The reason for using many thin sheets for forming the rotor body is that the eddy current losses generated due to magnetic flux passing through the rotor body may by this be kept at an acceptably low level.

The invention relates to such a rotor in machines intended for motor and/or generator operation and is not in any way restricted to the number of phases such a machine may have. The invention is also applicable to any number of poles and perma-
permanent magnets of the rotor and neither is it restricted with respect to operation voltages, powers and frequencies of said alternating current.

An advantage of an alternating current machine having such a rotor with respect to an asynchronous machine is that the power that may be generated per weight unit of the machine in motor operation gets considerably higher, which make such a motor particularly interesting in situations where a weight being as low as possible for generating a certain power is aimed at. However, the use of alternating current machines, especially motors, of this type has hitherto been restricted, since there has not been any way to easily produce them through a manufacturing process which is comparable to manufacturing of for example conventional asynchronous motors with respect to the degree of automatization.

Said thin sheets have namely until now been placed on top of each other and the permanent magnets have been introduced into said spaces and the end sheets have then been braced against the stack of the thin sheets by tightening bolts for stabilising the rotor body. The permanent magnets may then be directly arranged in said spaces or pieces of non-magnetic magnetisable material may be arranged therein and then be magnetised. This way to assemble said rotors is complicated and too inefficient for being commercially interesting for producing such machines in large series.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a method and a rotor of the type defined in the introduction, which find a remedy to the inconveniences mentioned above and make it possible to manufacture a rotor of this type in such a way that a production in series thereof gets commercially interesting.
This object is according to the invention obtained by providing a method, in which a securing of the sheets of the stack with respect to each other and of at least a first end sheet with respect to the stack takes place by a die casting step through introducing a molten cast compound into through holes extending through the sheets and by that the stack and the end sheet and against parts of the front face of this end sheet while applying a high pressure, the other, second end plate being secured to the stack either at the same time as the fist one in the same way as this or in a mechanical way after the die casting step has been terminated, as well as by providing a rotor according to the appended independent rotor claim.

By utilising the die casting technique in this way for producing rotors provided with permanent magnets the production may be substantially more efficient than the production methods used so far for rotors of this type. The costs for investments in machines for carrying out this method will also be low and are restricted to the modification of present tools for the die-casting. Furthermore, a rotor manufactured in this way will be considerably more dense = more compact, i.e. it will have a higher fill factor than rotors produced by utilising bolts or glueing for forming the rotor body. Another advantage is that the rotor body gets very stable and it gets a more uniform construction than in the case of using bolts for securing the thin sheets and the end sheets, which improves the operation performance of the electrical alternating current machine to which the rotor will belong. It has been the general opinion within this technical field that the die casting technique is not possible to use for production of rotors provided with permanent magnets, since it has been assumed that even non-magnetic magnetisable material is damaged during the die casting, but the present inventors have understood and verified that this is not the case and non-magnetic magnetisable material may very well be applied in the rotor body during the die casting step. However, it is pointed out that the present invention is not restricted to neither the use of non-magnetic magnetisable ma-
terial in the rotor bodies and that this is then magnetised nor
that such non-magnet magnetisable material is applied in the
rotor body at all when carrying out said die casting step, but in
certain applications of the invention it is well conceivable that
permanent magnets or pieces of non-magnetic magnetisable
material are introduced into said spaces after the die casting
step has been carried out.

According to a preferred embodiment of the invention the ar-
10 rangement of the permanent magnets takes place by introducing
pieces of non-magnetic magnetisable material into said spaces
and magnetising of these pieces takes place after the die-cast-
ing has been terminated. As mentioned above, it has been found
that it is possible to introduce such pieces into the spaces and
15 have there during the very die casting without damaging the
material for that sake, i.e. the material later on is magnetised in
a desired way. The manufacturing process may in some cases
be simplified by utilising this possibility.

According to another preferred embodiment of the invention both
20 end sheets are secured with respect to the stack by one single
die casting step, in which it is then pieces of non-magnetic mag-
netisable material that are introduced into said spaces. Such a
method gets very simple and by that advantageous from the cost
25 point of view, at the same time as the advantages mentioned
above with respect to high fill factor, uniform rotor construction
and so on are obtained.

According to another preferred embodiment of the invention the
30 permanent magnets are arranged in a plurality of layers ar-
anged one after another with respect to the direction of the axis
of rotation of the rotor, and the spaces of one layer are dis-
placed in the circumferential direction with respect to the spaces
35 of the subsequent layer. A rotor constructed in this way is ad-
vantageous from the power transmission point of view, and
some of the "permanent magnets" thereof have to be arranged
in said spaces before the die casting step is carried out, more exactly all of them except from those arranged in the layer located at that end where the second end sheet is to be applied, since there is no access to these spaces after the die casting step has been carried out. Pieces of non-magnetic magnetisable material are in such a case used for forming the "permanent magnets" to be located in the spaces during the die casting step.

According to another preferred embodiment of the invention only the first end sheet is secured to the stack through the die casting step, the die casting takes place while forming projections of solidified cast compound protruding from said holes out of the stack, and the second end sheet is secured to the stack by bringing this to bear against the stack while making said projections penetrating through holes in the end sheet and deforming a part of the respective projection extending past the end sheet following thereupon for riveting the second end sheet to the stack. The second end sheet may in this way be efficiently brought in place, and this way to proceed enables a combination of the die casting method and the direct arrangement of permanent magnets in the spaces in the stack, by doing this after the die casting step has been carried out, so that also magnetic material may be used for said pieces and still the advantages of utilising the die casting technique may be had.

Molten aluminium is preferably used as cast compound for filling said holes and cavities of a casting mold, in which this is introduced thereinto under a high pressure, in which the die casting preferably takes place by introducing the cast compound at a pressure of at least 500 bars and temperatures exceeding 700°C of the cast compound are utilised.

The advantages of the different embodiments of the rotor according to the invention defined in the claims appear as clearly as desired from the discussions above of preferred embodi-
ments of the method for producing such a rotor according to the invention.

Further advantages as well as advantageous features of the invention appear from the following description and the other dependent claims.

BRIEF DESCRIPTION OF THE DRAWING

With reference to the appended drawing, below follows a description of rotors according to two preferred embodiments of the invention as well as methods for production thereof.

In the drawings:

Fig. 1 is a view of a rotor according to a first preferred embodiment of the invention partially sectioned along a substantially axial plane, in which one end sheet has not been brought into place yet,

Fig. 2 is an axial end view of the rotor shown in Fig. 1 from the right with respect to Fig. 1 in which some parts have been broken away for illustrating the construction of the rotor, and

Fig. 3 is a view substantially corresponding to Fig. 2 of a rotor according to a second preferred embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A method for production of a rotor provided with permanent magnets for an electrical alternating current machine according to a first preferred embodiment of the invention will now be described by means of Fig. 1 and 2. A large number, for example
approximately 300, of thin sheets of a material having a high magnetic permeability, preferably iron or so called motor sheet, are laid on top of each other for forming the rotor body. The thin sheets may have a thickness of only a few tenths of millimetres for reducing the losses connected to eddy currents generated therein through magnetic flux going therethrough. The sheets are too thin for being shown in Fig. 1, but the shape of each of these sheets 1 appears from Fig. 2. These sheets have openings 2 distributed substantially uniformly in the circumferential direction, arranged close to the periphery and formed for example through punching out, said openings being in the present case 16 to the number, and which have such a cross section that they form spaces 3 extending in the longitudinal direction of the rotor body when the sheets 1 are superimposed and they are adapted to receive permanent magnets. Thus, uniformly is here and in the claims intended to comprise that the magnets are arranged for example in couples and the couples have substantially the same mutual distance. Furthermore, the sheets have holes 4, for example 4-8 to the number, and they are arranged internally of the openings 2 and preferably with a diameter of 6-10 mm. These holes are intended to be laid on top of each other for forming a through hole in the rotor body. Furthermore, the sheets 2 have internal wedge slots 5 for orientation thereof during the die casting method.

The rotor has also end sheets arranged on both sides of the thin sheets 1, of which only the first 7 is shown in Fig. 1. These end sheets are substantially thicker than the thin sheets 1 and may for example be formed by glueing approximately 10 thin sheets to each other, in which these end sheets have no openings 2, but they are provided with holes 4. The end sheets are therefore stabilising the rotor body by bracing them on both sides of the stack 6.

According to a first preferred embodiment of the invention the rotor is manufactured in the following way: A large number of
thin sheets 1 are laid on top of each other in a stack with respect to the direction of the axis of rotation of the rotor and are applied together with a first end sheet 7 in a casting tool, i.e. casting mould, of a die casting machine. The sheets are then so arranged that the holes 4 of the different thin sheets and the end sheet 7 cover each other. The same is valid for openings 2, but it is here possible to arrange a number of thin sheets having openings covering each other and then a following layer of thin sheets having openings covering each other but displaced with respect to openings of the preceding layer. A desired number of layers may be arranged in this way, in which permanent magnets will then accordingly be arranged in the axial direction one after another but mutually somewhat displaced, so that when the thin sheets are designed as in Fig. 2 the number of permanent magnets of the rotor will be 16 times the number of said layers.

When the stack and the first end sheet 7 have been put in the casting mould this is closed and a flowing cast compound in the form of molten aluminium is supplied to the holes 4 and recesses in the casting tool, so that a ring 8 will be produced externally of the end sheet 7 for securing thereof. The molten aluminium is then preferably supplied with a pressure of between 500-1 100 bars, and it has a temperature of 740-780°C. The temperature has to be that high, since the rotor body has many thin channels with a large cooling surface. Recesses are at one end of the casting mould made so that projections 9 or pins will protrude past the end of the stack 6.

When the die casting has been terminated and the body shown in Fig. 1 has solidified an end sheet not shown is brought from the end opposite to the position of the first end sheet 7 to abutment against the stack 6 while the projections 9 are penetrating through holes in the end sheet, whereupon the end of these projections is deformed for riveting the second end sheet to the stack, so that the cast compound solidified forms the connection member keeping the end sheets and by that the stack together.
However, before this is happening all the permanent magnets 10 or pieces of non-magnetic magnetisable material have to be introduced into the spaces 3 formed by the openings 2. In the case that pieces of non-magnetic magnetisable material are used for forming the permanent magnets of the rotor, these pieces may be put in place in the spaces 3 already before the die casting, but is magnetic material to be used it will be necessary to bring these in place in the spaces 3 after the die casting has been carried out, since the high temperatures resulting therein otherwise will destroy the magnetising of the permanent magnets. In the case that the layers mutually displaced mentioned above are applied it will be necessary to use pieces of non-magnetic magnetisable material for at least all layers except from the one closest to the second end sheet, since these pieces have to be arranged in place in the rotor body before the die casting process.

A rotor obtained in this way is uniform to the construction thereof and has a high fill factor, since the thin sheets will be arranged extremely tight pressed against each other.

It is illustrated in Fig. 3 how a rotor according to the invention may be produced according to a method according to a second preferred embodiment of the invention by applying the two end sheets 7-11 in place before the die casting step, and the casting tool is then, accordingly, designed in the same way as to the right in Fig. 1 on both sides of the rotor body. This method requires the arrangement of pieces of non-magnetic magnetisable material in place in the spaces 3 before the die casting step is carried out. This material will then be magnetised afterwards. This method gets extremely simple and requires a minimum of investment costs and small changes in the production flows already there for producing rotors for other alternating current machines, such as asynchronous motors, and the only thing required is the modification of the very casting tool, i.e. the casting mould.
It is shown in Fig. 1 and 3 how openings or apertures 2 are arranged in one single layer, in which then in spite of that a permanent magnet 10 may be applied from each end therein, but it would, as mentioned, be possible to arrange a plurality of such layers for obtaining better power transmitting properties and in some cases better operation properties of an alternating current machine with such a rotor.

The invention is of course not in any way restricted to the preferred embodiments described above, but many possibilities to modifications thereof will be apparent to a man skilled in the art without departing from the basic idea as defined in the claims.

The openings for the magnets and by that the magnets could of course have another cross section, which is also valid for the through holes for keeping the stack together through the rods resulting from the die casting, these openings or holes could be there to another number than shown in the figures and so on.

It is pointed out that the definition "non-magnetisable material" is in this disclosure intended to also comprise non-magnetic permanent magnets, while "permanent magnets" only comprises magnetised permanent magnets.
Claims

1. A method for producing a rotor of an electrical alternating current machine provided with permanent magnets (10), in which a large number of thin sheets of a material having a high magnetic permeability are fixed to each other arranged on top of each other in a stack (6) with respect to the direction of the axis of rotation of the rotor for forming a rotor body, permanent magnets are arranged in spaces (3), which are formed in said stack by arranging the sheets with openings (2) carried out therein substantially covering each other and which are distributed around the sheets close to the periphery thereof, and the rotor body is stabilised by bracing end sheets (7, 11) having a substantially greater thickness than said sheets on both sides of the stack, characterized in that a securing of the sheets of the stack with respect to each other and of at least a first end sheet (7) with respect to the stack takes place by a die casting step through introducing a molten cast compound into through holes (4) extending through the sheets and by that the stack and the end sheet and against parts (8) of the front face of this end sheet while applying a high pressure, the other, second end sheet (11) being secured to the stack either at the same time as the first one in the same way as this or in a mechanical way after the die casting step has been terminated.

2. A method according to claim 1, characterized in that the arrangement of the permanent magnets takes place by introducing pieces (10) of non-magnetic magnetisable material in said spaces (3) and magnetising these pieces after the die casting has been terminated.

3. A method according to claim 2, characterized in that at least some of said pieces (10) are placed in said spaces (3) before the die casting is carried out.
4. A method according to claim 2 or 3, characterized in that both end plates (7, 11) are secured with respect to the stack (6) by one single die casting step.

5. A method according to claim 3, characterized in that the permanent magnets (10) are arranged in a plurality of layers arranged one after another with respect to the direction of the axis of rotation of the rotor, and that the spaces of one layer are displaced in the circumferential direction with respect to the spaces of the subsequent layer.

6. A method according to any of claims 1-3 or 5, characterized in that only the first end sheet (6) is secured with respect to the stack (6) by the die casting step, that at least some of the permanent magnets are introduced into said spaces (3) from the end of the stack opposite to the first end sheet after the die casting, and that the second end sheet (11) is then mechanically secured to the stack.

7. A method according to any of claims 1-3, 5 or 6, characterized in that only the first end sheet (7) is secured to the stack (6) through the die casting step, that the die casting takes place while forming projections (9) of solidified cast compound protruding from said holes (4) out of the stack, and that the second end sheet (11) is secured to the stack by bringing this to bear against the stack while making said projections penetrating through holes in the end sheet and deforming a part of the respective projection extending past the end sheet following thereupon for riveting the second end sheet to the stack.

8. A method according to claims 6 or 7, characterized in that it is permanent magnets (10) which are introduced into said spaces (3) in the stack and all the permanent magnets are introduced into the spaces after the die casting step.
9. A method according to any of claims 1-8, characterized in that said magnets (10) are applied in the rotor body circumferentially substantially uniformly distributed with a pitch corresponding to more than 8 and preferably more than 12 magnets over one turn.

10. A method according to claim 9, characterized in that 16 permanent magnets are arranged over one turn.

11. A method according to claims 1-10, characterized in that said through holes (4) are arranged in the sheets internally of said spaces (3) for the permanent magnets with respect to the axis of rotation of the rotor, and that there are at least 3, preferably 4-8, such through holes which are filled by cast compound in the die casting step.

12. A method according to any of claims 1-11, characterized in that molten aluminium is introduced into said through holes (4) and cavities of a casting mould under high pressure during the die casting step.

13. A method according to any of claims 1-12, characterized in that the die-casting takes place by introducing the cast compound with a pressure of at least 500 bars into said holes (4).

14. A method according to any of claims 1-13, characterized in that the die-casting takes place by introducing a molten cast compound having a temperature exceeding 700°C into said holes (4).

15. A rotor for an electrical alternating current machine, which is provided permanent magnets (10) and formed by a number of thin sheets of a material having a high magnetic permeability, secured to each other and superimposed in a stack (6) with respect to the direction of the axis of rotation of the rotor for forming a rotor body, said permanent magnets being arranged in
spaces (3) formed in said stack through arranging the sheets with openings (2) carried out therein substantially covering each other, and these spaces are distributed around the sheets close to the periphery thereof, said rotor body being stabilised by end sheets (7, 11) braced on both sides of the stack and having a substantially greater thickness than the sheets of the stack, characterized in that the sheets of the stack are secured to each other and at least a first end sheet (7) is secured with respect to the stack by a cast compound introduced into through holes (4) extending through the sheets and by that through the stack and the end sheet in a die casting step and solidified, said cast compound also bearing against parts (8) of the front face of this end sheet, and that the other, second end sheet (11) is secured to the stack in the same way as the first one or mechanically.

16. A rotor according to claim 15, characterized in that only the first end sheet (7) is secured with respect to the stack (6) by the cast compound emanating from the die casting step and the second end sheet (11) is mechanically secured to the stack.

17. A rotor according to claim 16, characterized in that it comprises projections (9) of cast compound solidified protruding out of the stack (6) from said holes (4), said projections penetrating through holes in the second end sheet and being terminated by rivet head-like portions emanating from a deformation of the end thereof and adapted to maintain the second end sheet (11) against the stack.

18. A rotor according to claim 15, characterized in that both end sheets (7, 11) are secured with respect to the stack (6) by cast compound emanating from the die casting step and extending through holes (4) thereof and of the stack (6) as well as bearing against parts (8) of the front face of the respective end sheet.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02K 15/03, H02K 1/27
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)

IPC7: H02K

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

SE, DK, FI, NO classes as above

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>A</td>
<td>EP 0712198 A1 (SEIKO EPSON CORPORATION), 15 May 1996 (15.05.96), column 4, line 46 - column 6, line 51; column 9, line 9 - line 46</td>
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Date of the actual completion of the international search 6 December 1999

Date of mailing of the international search report 07-12-1999

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