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(71) Applicant *(for all designated States except US)*: STRIDSBERG INNOVATION AB [SE/SE]; Tanneforsvägen 14, S-122 47 Enskede (SE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: STRIDSBERG, Lennart [SE/SE]; Tanneforsvägen 14, S-122 47 Enskede (SE).

(74) Agents: LINDÉN, Stefan et al.; Bergenstråhle & Lindvall AB, P. O. Box 17704, S-118 93 Stockholm (SE).

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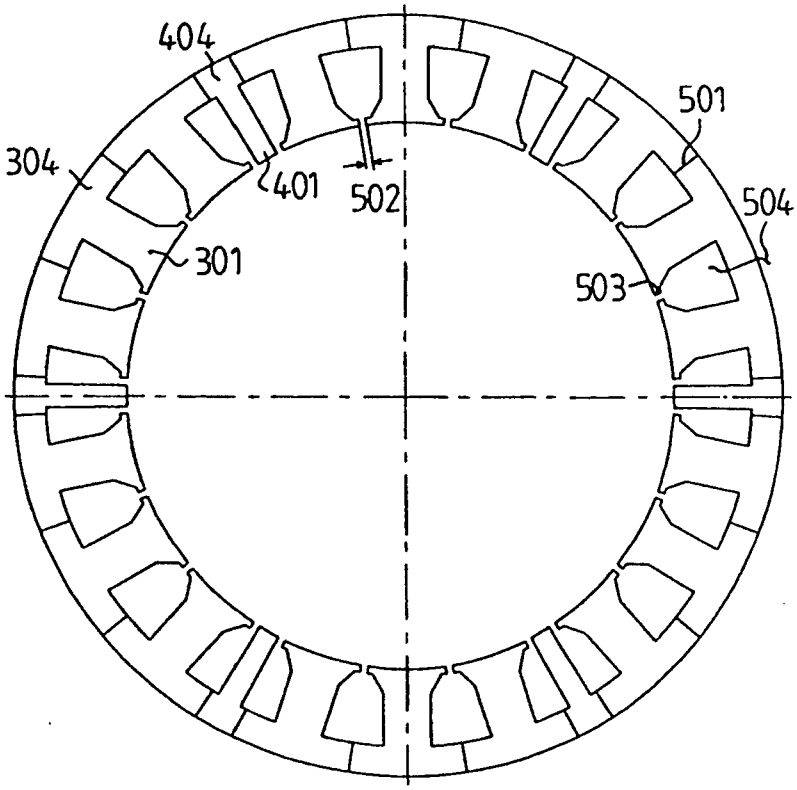
(57) Abstract

In a brushless electric motor/generator there are poles (301, 401) which are separate mechanical parts and are assembled to form a stator. The poles (301, 401) comprises outer portions (304, 404) projecting in a circumferential direction from the main leg of the poles. These outer portions (304, 404) are engaged with each other, thus forming a magnetic yoke carrying magnetic flux between the poles. This permits an easy winding of the separate poles and a good support thereof by an outer ring.



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AN ELECTRIC MOTOR AND ITS FABRICATION

Technical Field

The invention is concerned with methods of designing and producing stators for in particular brushless motors/generators and the motor/generator stators and motors/generators thus produced.

Background of the invention and prior art

To obtain highly efficient electrical motors some requirements are commonly understood. The design should give short amounts of current conducting winding material that is outside the stator parts that are highly permeable for magnetic flux. The design should also permit much current conducting winding material in the winding slots. Further, the thermal path between the current conducting winding material and the intermediate heat sink like the outer housing of the motor should be good enough to keep the winding temperature at an acceptable level at power losses that the outer casing can dissipate at acceptable surface temperatures. The design should also give stators that are mechanically robust.

Brushless DC motors have their windings in the stator. Most stators are three-phase and have stator windings similar to that of a three phase induction motor.

Almost all electric motors with alternating current stator windings (including brushless DC motors and induction motors) in sizes up to some 10 kW have their stators made of lamination sheets that cover the whole circumference of the motor. These punched laminations are assembled together by welding or other means to form a rigid hollow cylinder. Thereafter the winding slots are insulated. The windings are wound outside the stator and thereafter inserted in the slots. This method does give two disadvantages.

The first disadvantage is that it does not permit a very orderly arrangement of the winding wires in the winding slots. In order to obtain a very high utilization of a winding slot in a stator, the wires should run parallel to each other. For wires of circular cross-section, a hexagonal arrangement where each wire is surrounded by six other wires is normally the most efficient arrangement.

The second disadvantage is that a prewound winding coil must

have a considerable surplus length to permit insertion in a stator winding slot. In the case of overlapping polyphase windings, a certain excess length is required to permit insertion of a winding without being locked by the other phases. In the case of salient poles, a certain excess length is required to as the winding must be heeled over the pole tooth head portions. This results in unnecessary current conducting winding material that is outside the stator parts that are highly permeable for magnetic flux.

Figure 1 illustrates a rolled-out view of a conventional stator with overlapping phases as seen from the rotor.

The arc 101 shows one part of the current conducting winding 104 that is not inserted inside the flux permeable part of the stator, while 103 shows a part that is inserted inside the flux permeable part of the stator. 102 shows the stator pole as seen from the rotor.

Figure 2 illustrates a rolled-out view of a conventional stator as seen from the rotor of a brushless motor as disclosed in the published International patent application WO-A1 92/06530. These motors, and motors as disclosed in the published International patent application WO-A1 93/15547, have windings consisting of groups of stator poles 201, each having a simple coils 202 around it. In the case of motors as disclosed in the cited International patent application WO-A1 92/06530, the gaps between different pole groups are bridged by balancing poles 203.

A common problem in the winding of motor stators is to reduce the amounts of current conducting winding material that is outside the flux high permeable stator parts. This material is shown separately as 101 and 204 in figures 1 and 2 respectively.

The US patent 3,792,299 discloses a stator for an electric motor comprising an outer annual yoke and a plurality of radially directed stator teeth. In another embodiment (figure 7) in the same patent, the yoke is assembled of a plurality of yoke parts. In both cases, the flux carrying parts of the stator consists of separately punched stator teeth. The winding of the stator is made by first arranging the stator teeth so that during the winding procedure, the slot spaces for the stator winding will be open radially outwards. This permits a winding with far less surplus length as there is more freedom in adjusting the coils of

the different phases of the winding to each other during assembly. After the winding procedure these openings are closed by a stator ring or yoke, whereafter moulding together of winding, stator teeth and stator yoke is carried out by means of lacquer or moulding compound to a rigidly assembled stator unit.

The US patent 3,353,046 discloses a stator produced from a cog-wheel shaped stator teeth set. After winding, impregnation with a thermosetting resin and baking, the resulting solid body is ground down to an outer diameter that fits an outer, cylinder shaped yoke ring. After that the yoke cylinder is assembled and fixed by another impregnation and baking process, the common base of all the stator teeth is ground down from the inside so that the base disappears and the required gaps between each stator tooth appears.

The US patents 2,459,673, 2,517,105, 2,654,037, 2,655,613, 2,687,483, 2,691,113, 2,745,031, 3,449,607, 3,549,926, 3,612,930, 3,740,600, 4,246,505, 4,433,262 and 4,816,710 and the published International patent application WO-A1 92/10021 disclose various ways to design electrical machines with yokeless separate salient poles which are assembled on a stator or rotor yoke. Most or all of these designs have solid (not laminated) poles and/or yokes and seem to be designed exclusively for poles with DC current coils to be used as stator field magnets (interacting with laminated rotors in mechanically commutated DC machines) or rotor poles for synchronous machines (interacting with laminated three-phase stators).

The published International patent application WO-A1 92/03870 discloses a design where laminated salient poles can be assembled into a laminated stator yoke. The assembled stator shape corresponds to stators commonly as field in a mechanically commutated DC machine).

Summary

A purpose of the invention is to provide a brushless motor stator that permits much current conducting winding material in the winding slots.

Another purpose of the invention is to provide a brushless motor stator that give short amounts of current conducting winding material that is outside the stator parts that are highly permeable for magnetic flux.

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