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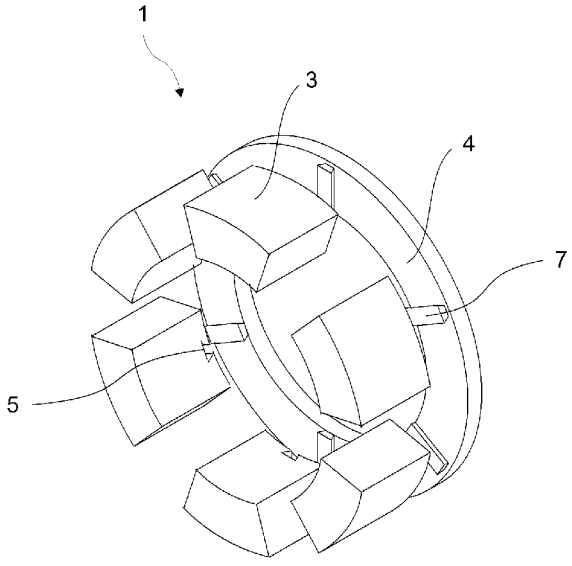
(54) Title: PERMANENT MAGNET AXIAL-FLUX ELECTRIC MACHINE STATOR AND ROTOR ASSEMBLIES

Fig. 1



(57) Abstract: The present invention relates to an axial flux electric machine comprising a stator assembly (1) and a rotor assembly (2), said stator assembly (1) having a stator yoke (4) and stator teeth (3) with windings wound around said stator teeth (3), said rotor assembly (2) having a rotor yoke (6) and a plurality of permanent magnets (9) attached to said rotor yoke (6).

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Description

PERMANENT MAGNET AXIAL-FLUX ELECTRIC MACHINE STATOR AND ROTOR ASSEMBLIES

[0001] The present invention relates to permanent magnet axial-flux electric machine stator and rotor assemblies.

[0002] It is well-known that permanent-magnet synchronous motors (PMSM) are motors having high efficiency, operating without excitation windings and with electronic switching. These motors are widely used due to their desirable properties. PMSMs are categorized as radial, axial and transverse depending on the direction of the magnetic flux. Radial flux motors are the most common due to their similar structure to conventional motors, lamination and windings and ease of manufacture. Axial flux motors are less common because they require a different structure or use of insulated pure iron powder or so called Soft Magnetic Composite (SMC).

[0003] In recent years, axial flux motors have become common in a wider range of applications due to advances in material science. Axial flux permanent magnet machines have their distinct advantages over radial flux permanent magnet machines in that they require less core material due to higher power-to-weight ratio and as a result of the disc shaped rotor and stator structure, smaller size as well as reduced complexity is ensured. Compared to radial flux motors, axial flux motors have higher power and torque density (W/m^3, Nm/m^3). As high output power can be obtained with small motor sizes, axial flux type motors are being used more and more, especially in applications such as electric cars, bikes and wind turbines.

[0004] Among others, a prior art publication in the technical field of the invention may be referred to as US2008061649, which discloses an axial gap motor in which a stator and a rotor are arranged parallel to a rotating shaft. More particularly, the publication discloses an axial gap motor, which can be easily manufactured and achieve an improvement in efficiency. In the axial gap motor the stator includes a back yoke defining a magnetic path, a plurality of stator cores each having a central portion parallel to the rotating shaft, each of the plurality of stator cores being coupled to the back yoke,

and a plurality of stator coils, each wound around the central portion of a corresponding one of the stator cores.

[0005] Other examples may be referred to as US20110025161, US20140285048, EP1593190 and US6707221. US20110025161 discloses an axial flux stator including a plurality of magnetically permeable members, a plurality of windings, a back iron, and an encasing. The plurality of windings is associated with the plurality of magnetically permeable members to produce a plurality of winding-magnetically permeable member assemblies. The back iron is mechanically butt joint coupled to the plurality of winding-magnetically permeable member assemblies. The encasing maintains the butt joint coupling of the back iron to the plurality of winding-magnetically permeable member assemblies.

[0006] As axial flux motors are not suited to be manufactured by lamination and the unsuitability of lamination to the direction of flux, these motors are manufactured by soft magnetic composite (SMC) materials. SMC materials do not have high mechanical strength, so winding the windings around teeth poses another problem. Therefore it would be more advantageous to use SMC materials together with ferromagnetic materials in manufacture of axial flux motors.

[0007] The present invention, addresses the situation where SMC materials and ferromagnetic materials are used together to manufacture axial flux motors.

[0008] The present invention provides a singular manufacturing form for manufacturing both stator and rotor yokes and teeth are conveniently assemblable with the stator yoke in a practical manner. Therefore, the present invention is devised under the recognition that an axial flux electric machine can be manufactured in a substantially facilitated manner.

[0009] The present invention provides permanent magnet axial-flux electric machine stator and rotor assemblies as provided by the characterizing features defined in Claim 1.

[0010] Primary object of the present invention is to provide permanent magnet axial-flux electric machine stator and rotor assemblies assemblable in a substantially facilitated manner.

[0011] The present invention proposes an axial flux electric machine comprising a stator assembly and a rotor assembly. The stator and rotor yokes are shaped identically with a common geometry so as to contain projections corresponding to the number of stator teeth. While each of stator and rotor yokes is made of laminated sheets, stator teeth are manufactured using soft magnetic composite materials. Stator teeth are wound in an unassembled condition of the stator teeth with the stator yoke and then attached to the stator yoke.

[0012] Accompanying drawings are given solely for the purpose of exemplifying permanent magnet axial-flux electric machine stator and rotor assemblies, whose advantages over prior art were outlined above and will be explained in brief hereinafter.

[0013] The drawings are not meant to delimit the scope of protection as identified in the Claims, nor should they be referred to alone in an effort to interpret the scope identified in said Claims without recourse to the technical disclosure in the description of the present invention. The drawings are only exemplary in the sense that they do not necessarily reflect the actual dimensions and relative proportions of the respective components of the system.

[0014] Fig. 1 demonstrates an exploded view of the stator assembly with a stator yoke and stator teeth according to the present invention.

[0015] Fig. 2 demonstrates a non-hidden wireframe view of the stator assembly with the stator yoke and stator teeth in assembled condition according to the present invention.

[0016] Fig. 3 demonstrates an exploded view of the rotor assembly with the rotor yoke and permanent magnets according to the present invention.

[0017] Fig. 4 demonstrates a non-hidden wireframe view of the rotor assembly with the rotor yoke and permanent magnets in assembled condition according to the present invention.

[0018] Fig. 5 demonstrates a top view of the rotor assembly with the permanent magnets in assembled condition according to the present invention.

[0019] The following numerals are assigned to different part number used in the detailed description:

[0020] 1) Stator assembly

[0021] 2) Rotor assembly

[0022] 3) Stator teeth

[0023] 4) Stator yoke

[0024] 5) Teeth slot

[0025] 6) Rotor yoke

[0026] 7) Projection

[0027] 8) Permanent magnet

[0028] 9) Permanent magnet slot

[0029] The present invention relates to permanent magnet (8) axial-flux electric machine stator and rotor assemblies (1 and 2).

[0030] The invention provides ease of manufacture of axial flux motors by production of stator and rotor yokes (4, 6) with a common geometry instead of production of the stator and rotor from insulated pure iron powder (Soft Magnetic Composite (SMC)).

[0031] Both of the stator and rotor yokes (4, 6) are manufactured from ferromagnetic materials advantageously using a single mold. Stator and rotor yokes (4, 6) contain projections (7) corresponding to the number of stator teeth (3). Stator teeth (3) produced from SMC materials have slots (teeth slot (5)) on their bottom surface for attaching to said projections (7). In this manner, the stator teeth (3) containing the windings are attached to the stator yoke (4) and the stator assembly (1) is completed.

[0032] Permanent magnets (8) are attached to the rotor yoke (6) in a similar manner. In accordance with the present invention, permanent magnets (8) consist of two types: one having a slot (permanent magnet slot (8)) and one not having a slot on its bottom surface. Permanent magnets (8) not having a slot are insertable between two neighboring projections (7) on the rotor yoke (4) to obtain a symmetrically distributed permanent magnet (8) configuration because permanent magnets (8) and stator teeth (3) are attached to respective yokes with the same physical structure and there exist more stator teeth (3) compared to permanent magnets (8). Said permanent magnets (8) having a slot are attached onto the projections (7). Different magnet types can be inserted sequentially so as to obtain the

rotor assembly (2).

[0033] In accordance with the present invention, stator teeth (3) are manufactured using SMC materials and are wound separately to be attached to the stator yoke (4), therefore providing ease of manufacture. Projections (7) on the stator yoke (4) are positioned at suitable predetermined angles, therefore fastening stator teeth (3) onto the stator yoke (4) can be easily carried out. Likewise, permanent magnets (9) are attached to the rotor yoke (4) through respective projections (7) thereon. Therefore, a simple and practical solution is provided for positioning permanent magnets (9) on the rotor assembly (2).

[0034] As a result, stator and rotor yokes (4, 6) can be manufactured as a single piece, reducing manufacturing complexities. SMC material and ferromagnetic sheet lamination are used in combination to obtain stator and rotor assemblies (1 and 2). Stator yoke (4) is typically made of laminated sheets in the manner that the yoke's upper surface is processed to form projections (7) through which said stator teeth (3) are attached. Stator teeth (3) made from SMC material and having ready-made windings are then inserted onto said projections (7). Rotor yoke (4) has the same geometry. This method is suitable for manufacturing rotor-stator yokes for all axial flux motor combinations having 3n:2n slot pole combinations, where n=1,2,3… is an integer. In this manner, one type manufacture is made possible.

[0035] Permanent magnets (9) are attached to the projections (7) on the rotor yoke (6), also manufactured by laminated ferromagnetic material. As slot pole combination is 3n:2n, while one permanent magnet (9) is attached onto a projection (7), the adjacent permanent magnet is inserted between two projections (7). In this manner the magnets are aligned and fixed in place. The projections (7) extend in radial directions.

[0036] Figures 1 and 2 illustrate stator yokes (4) and stator teeth (3) separately. Figures 3 and 4 illustrate the rotor assembly (2). Rotor yoke (6) is manufactured from the same components as the stator yoke (4).

[0037] In a nutshell, the present invention proposes an axial flux electric machine comprising a stator assembly (1) and a rotor assembly (2), said stator

assembly (1) having a stator yoke (4) and stator teeth (3) with windings wound around said stator teeth (3), said rotor assembly (2) having a rotor yoke (6) and a plurality of permanent magnets (9) attached to said rotor yoke (6).

[0038] In one aspect of the present invention, said stator and rotor yokes (4, 6) are shaped identically with a common geometry so as to contain projections (7) corresponding to the number of stator teeth (3).

[0039] In a further aspect of the present invention, each of stator and rotor yokes (4, 6) is made of laminated sheets.

[0040] In a further aspect of the present invention, stator teeth (3) are manufactured using soft magnetic composite materials.

[0041] In a further aspect of the present invention, stator teeth (3) are wound in an unassembled condition of the stator teeth (3) with the stator yoke (4) and then attached to the stator yoke (4).

[0042] In a further aspect of the present invention, stator teeth (3) comprise teeth slot (5) on their bottom surface for attachment with said projections (7).

[0043] In a further aspect of the present invention, permanent magnets (8) comprise permanent magnet slot (5) on their bottom surface for attachment with said projections (7).

[0044] In a further aspect of the present invention, permanent magnets (8) are fixedly attached to the rotor yoke (6) between two neighboring projections (7).

[0045] In a further aspect of the present invention, each of stator and rotor yokes (4, 6) is made of laminated sheets in the manner that the yoke's upper surface is processed to form projections (7).

[0046] In a further aspect of the present invention, the axial flux electric machine has 3n:2n slot pole combinations, where n is an integer.

[0047] The present invention provides a singular form yoke for use as both a stator as well as rotor yoke. This common structure allows for an axial flux electric machine having 3n:2n slot pole combinations, where n is an integer thanks to

[0048] permanent magnets (8) attachable with the projections (7) of the rotor yoke (6) or attached thereto between two neighboring projections (7).

Claims

1. An axial flux electric machine comprising a stator assembly (1) and a rotor assembly (2), said stator assembly (1) having a stator yoke (4) and stator teeth (3) with windings wound around said stator teeth (3), said rotor assembly (2) having a rotor yoke (6) and a plurality of permanent magnets (9) attached to said rotor yoke (6), **characterized in that**;
   said stator and rotor yokes (4, 6) are shaped identically with a common geometry so as to contain projections (7) corresponding to the number of stator teeth (3).
2. An axial flux electric machine as in Claim 1, **characterized in that** each of stator and rotor yokes (4, 6) is made of laminated sheets.
3. An axial flux electric machine as in Claim 1 or 2, **characterized in that** stator teeth (3) are manufactured using soft magnetic composite materials.
4. An axial flux electric machine as in Claim 1, 2 or 3, **characterized in that** stator teeth (3) are wound in an unassembled condition of the stator teeth (3) with the stator yoke (4) and then attached to the stator yoke (4).
5. An axial flux electric machine as in Claim 1, 2, 3 or 4, **characterized in that** stator teeth (3) comprise teeth slot (5) on their bottom surface for attachment with said projections (7).
6. An axial flux electric machine as in Claim 1 or 5, **characterized in that** permanent magnets (8) comprise permanent magnet slot (5) on their bottom surface for attachment with said projections (7).
7. An axial flux electric machine as in Claim 1 or 5, **characterized in that** permanent magnets (8) are fixedly attached to the rotor yoke (6) between two neighboring projections (7).
8. An axial flux electric machine as in any preceding Claim, **characterized in that** each of stator and rotor yokes (4, 6) is made of laminated sheets in the manner that the yoke's upper surface is processed to form projections (7).
9. An axial flux electric machine as in any preceding Claim, **characterized in that** the axial flux electric machine has 3n:2n slot pole combinations, where n is an integer.

Fig. 1

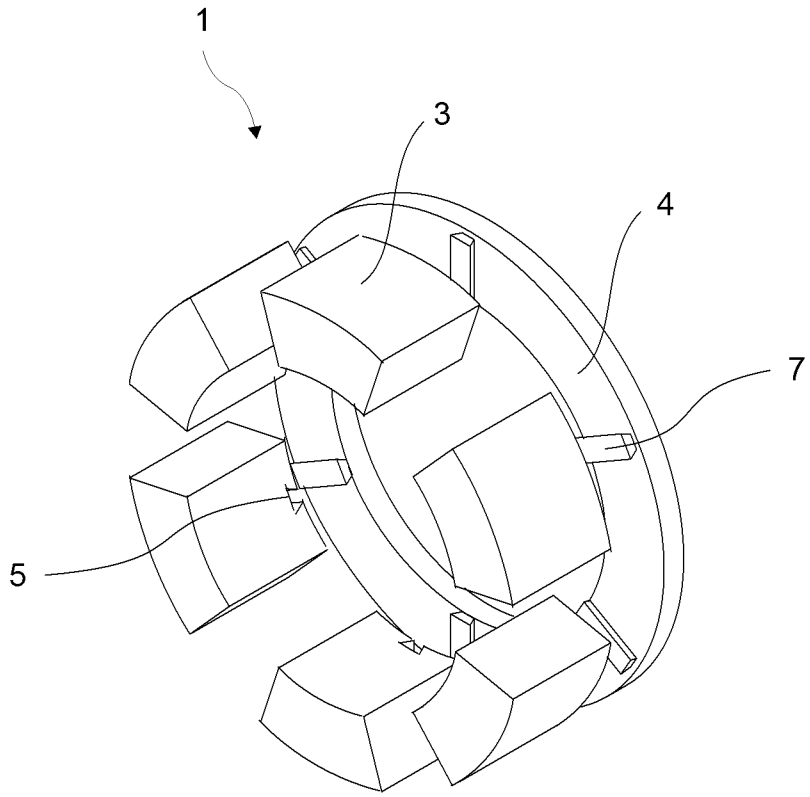


Fig. 2

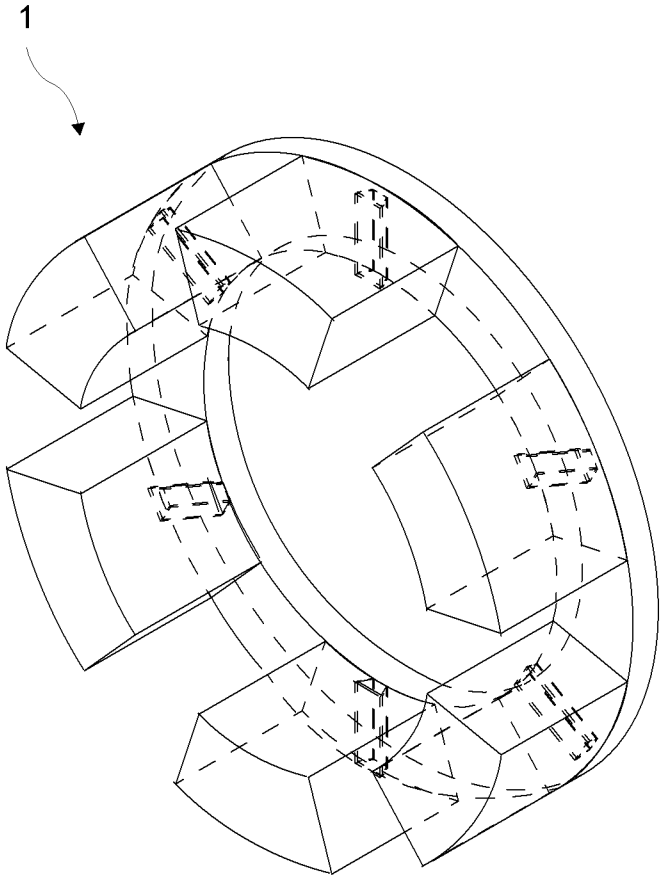


Fig. 3

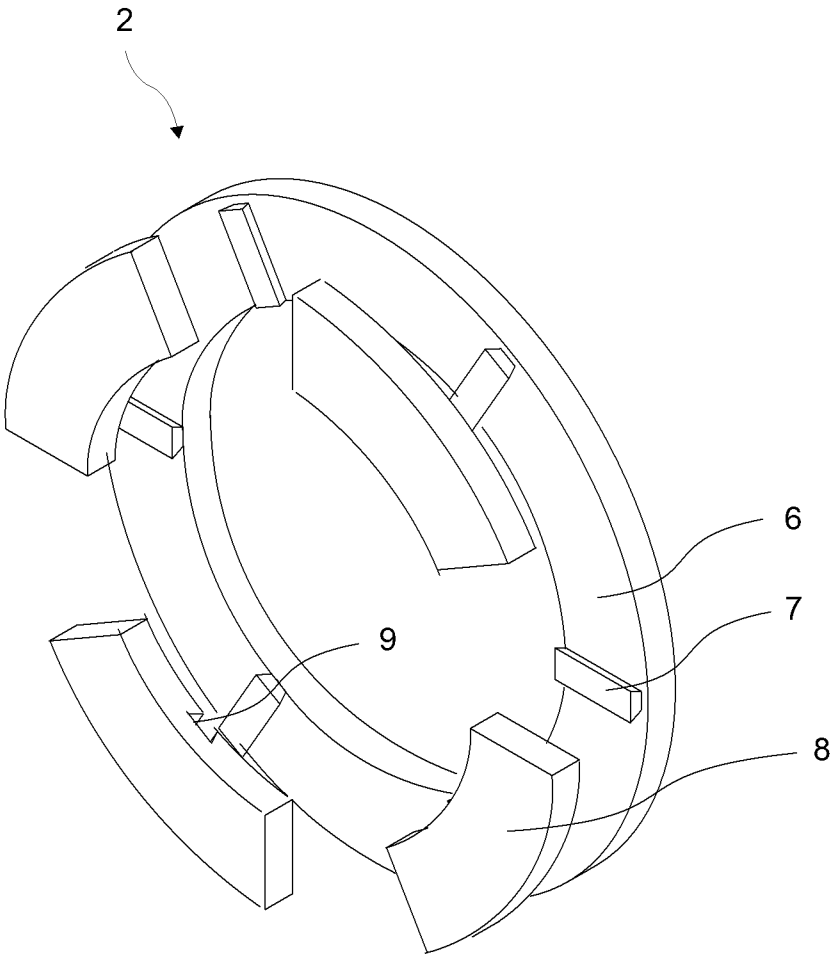


Fig. 4

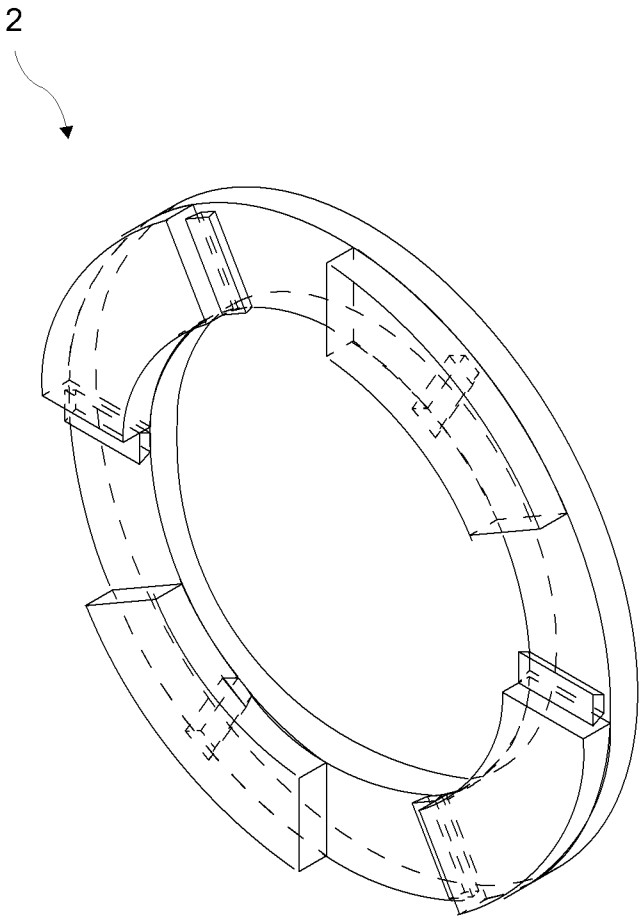
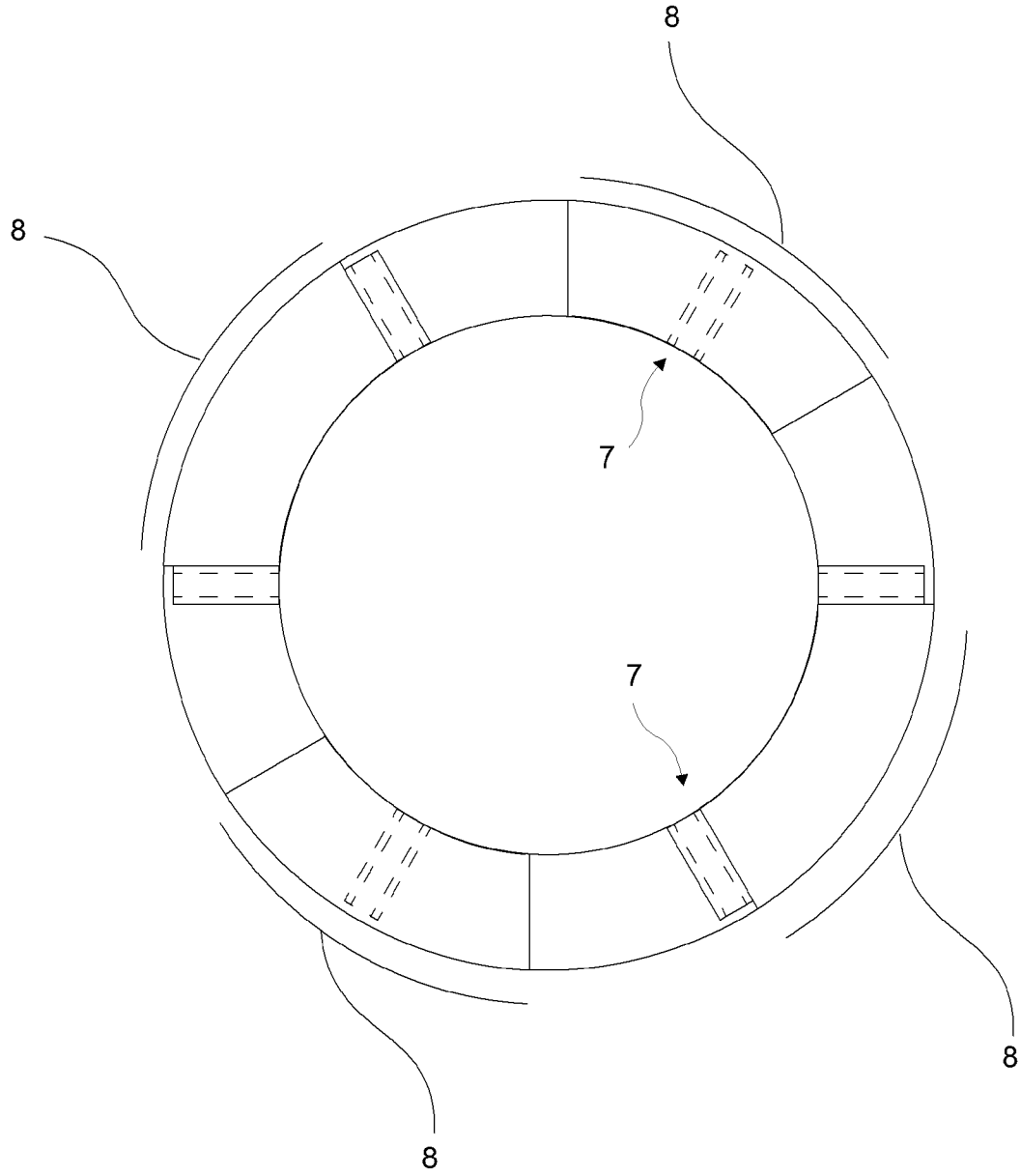


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/055667

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02K21/24 H02K1/27 H02K1/28
ADD.

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/071576 A1 (CHO YUN-HYUN [KR]) 6 April 2006 (2006-04-06) paragraph [0008] - paragraph [0011]; figures 4a-8a paragraph [0026] - paragraph [0032]; figures 9a,9b	1-9
A	JP 2003 079120 A (ASMO CO LTD) 14 March 2003 (2003-03-14) abstract; figures 13,14	5
A	EP 1 418 657 A1 (YAMAHA MOTOR CO LTD [JP]) 12 May 2004 (2004-05-12) paragraph [0035] - paragraph [0039]; figures 3,4	4,7

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/055667

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