



(51) International Patent Classification:

H02K 1/27 (2006.01) *H02K* 9/06 (2006.01)
H02K 1/28 (2006.01) *F01D* 5/02 (2006.01)
H02K 21/12 (2006.01)

(21) International Application Number:

PCT/FI2013/051103

(22) International Filing Date:

25 November 2013 (25.11.2013)

(25) Filing Language:

Finnish

(26) Publication Language:

English

(30) Priority Data:

20126241 26 November 2012 (26.11.2012) FI

(71) Applicant: **SAIMAAN AMMATTIKORKEAKOULU OY** [FI/FI]; Skinnarilankatu 36, FI-53850 Lappeenranta (FI).

(72) Inventors: **PUKKI, Timo**; Tammitie 6, FI-53810 Lappeenranta (FI). **SOPANEN, Jussi**; Toukkalantie 264A, FI-54710 Lemi (FI). **LIPPONEN, Aki**; Sunisenkatu 9 B 29, FI-53810 Lappeenranta (FI). **NERG, Janne**; Mottikatu 5, FI-53850 Lappeenranta (FI). **PYRHÖNEN, Juha**; Mäyräkatu 31, FI-53850 Lappeenranta (FI).

(74) Agent: **PAPULA OY**; P.O. Box 981, FI-00101 Helsinki (FI).

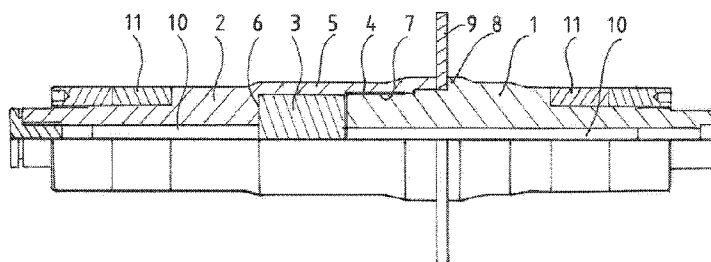
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: ROTOR AXLE OF A HIGH SPEED PERMANENT MAGNET MACHINE



(57) Abstract: The invention relates to a rotor axle of a high speed permanent magnet machine including a first part (1) and a second, part (2), both manufactured from a magnetically non-conducting material. The parts include an inner end and an outer end, and they can be axially interconnected one after the other by the inner ends to constitute an integral rotor axle. Their outer ends include bearing structures (11) to fit the rotor axle with bearings. A cylindrical and solid permanent magnet (3) is provided coaxially with the first part and the second part in between them and magnetized perpendicularly to the axial direction of the cylinder. According to the invention, the inner end of the first part (1) of the rotor axle includes a cylindrical external surface with an external thread (4). In addition, the inner end of the second part (2) includes a cylinder sleeve (5) having an internal base part (6) corresponding in shape to the cylindrical permanent magnet (3) so as to constitute a space for the permanent magnet, and an internal lining having an internal thread (7) corresponding to the external thread of the first part. This way, when the first part and the second part are concentrically rotated together one after the other in the axial direction, the permanent magnet (3) is provided in its space between the parts.

ROTOR AXLE OF A HIGH SPEED PERMANENT MAGNET MACHINE

FIELD OF THE INVENTION

The invention relates to a rotor axle of a high speed
5 permanent magnet machine according to the preamble of
claim 1.

BACKGROUND OF THE INVENTION

The prior art in the field of the invention has been
10 disclosed in patent publications EP 0418304 B1, EP
0956634 B1 and US 2004/0051416 A1. Known from the pub-
lications are rotors of high speed machines provided
with permanent magnets which are efficient, but rela-
tively fragile, consisting of rare earth metals. Due
15 to the mechanical properties of the magnets, they are
enclosed within a magnetically non-conducting tube or
sleeve. The magnet may be fastened centrally in the
sleeve with an interference fit, or it is also possi-
ble to manufacture the magnet directly inside the
20 sleeve from a powder. Then, axle end pieces are gener-
ally fastened with an interference fit at both ends of
the sleeve and welded together with the sleeve for
greater securement.

25 The structures disclosed above work, but they encom-
pass several disadvantages particularly in terms of
manufacture. Due to many interference fits, it is dif-
ficult to assemble the structure, which requires spe-
cial tools. The welding used for the structures makes
30 them disposable, i.e. they cannot be disassembled
without damaging the structures. In addition, it is
impossible to modify them for different size classes
due to the fixed structure. Furthermore, the setup of
the assembly is problematic due to many successive in-
35 terference fits. Further, it is difficult to fit the

axles with bearings in the axial direction, which requires complex structures.

OBJECTIVE OF THE INVENTION

5 The objective of the invention is to remedy the above-mentioned defects of the prior art. Specifically, the objective of the invention is to disclose a novel rotor axle of a high speed permanent magnet machine with the smallest possible number of simple parts, able to
10 be assembled and also disassembled in a simple and easy way, allowing simple implementation of the axial bearing and able to be easily modified for different size classes.

15 SUMMARY OF THE INVENTION

The rotor axle of a high speed permanent magnet machine according to the invention includes a first part and a second part, both manufactured from a magnetically non-conducting material. The first part and the
20 second part both have an inner end and an outer end so that they can be axially interconnected one after the other by the inner ends to constitute an integral rotor axle. Their outer ends have bearing structures to fit the rotor axle with bearings for rotation. Fur-
25 ther, a cylindrically shaped, solid permanent magnet is provided coaxially with the first part and the second part in between them and magnetized perpendicularly to the axial direction of the cylinder. According to the invention, a cylindrical external surface is
30 provided at the inner end of the first part, i.e. towards the center of the rotor axle, and has an external thread. Correspondingly, a cylinder sleeve is provided at the inner end of the second part, i.e. towards the first part. The internal base part of the
35 cylinder sleeve corresponds in shape to the cylindrical permanent magnet used so as to constitute a tight

and substantially backlash-free space for the permanent magnet. Further, the outer edge of the internal lining of the cylinder sleeve has an internal thread corresponding to the external thread of the first part and allowing the first part and the second part to be concentrically and axially interconnected one after the other by the corresponding threads. This way, when the permanent magnet is provided in its space in the second part, and the first part and the second part are rotated together, it is pressed and locked in its space between the first part and the second part.

Preferably, the first part and the second part are made of the same magnetically non-conducting material which is suitably metal, such as steel, for example stainless steel. It is also possible to make them of titanium or a composite suitable for the purpose, including for example carbon fiber.

In one embodiment of the invention, the first part of the rotor axle includes a shoulder which is radial, i.e. perpendicular to the longitudinal direction of the axle, around the axle. A corresponding radial, straight and ring-shaped surface is also provided to the edge surface of the second part. This way, as the first part and the second part are joined by the corresponding threads, an annular space is formed between the peripheral edge of the cylinder sleeve of the second part and the shoulder. An annular disc can be placed in this annular space before joining the parts. When the thickness of the annular disc is suitably selected, it is tightly pressed in its place between the first part and the second part as they are rotated together.

Said annular disc may act as a plate transmitting the magnetic force of the axial bearing of the rotor axle. The disc may also have mainly radial formations, such as grooves, channels or the like, in which case it may
5 act as a fan to provide an air flow cooling the different parts of the machine. It is also possible that the same annular disc acts as a plate transmitting the magnetic force of the axial bearing and as a fan at the same time.

10

In one embodiment of the invention, the first and the second part are hollow objects provided with a central hole. The hole extending through the second part allows inserting a tightly fitting permanent magnet in
15 its position, while air is able to flow out through the hole. In the same way, it is possible to remove the magnet by pushing it through the hole. Further, the inner end of the central hole of the first part can be provided with a tightening screw which is ro-
20 tated through the hole so as to press and tighten the magnet towards the base of the magnet space. This way, the magnet can be locked in its position.

In one embodiment of the invention, the rotor axle in-
25 cludes an alternative second part. Depending on the size of the magnet needed in an application, second parts of different lengths can be connected to the same first part of the axle, with the internal base part corresponding in shape to a cylindrical permanent
30 magnet of an alternative size. This way, every part of the rotor axle need not be manufactured individually for each application, but the first part may be the same each time and only the second part be dimensioned according to the size and properties of the magnet as
35 needed.

ADVANTAGES PROVIDED BY THE INVENTION

The rotor axle according to the invention has considerable advantages over the prior art. The rotor axle of a high speed permanent magnet machine according to the invention can be manufactured from a smaller number of parts than the corresponding known structures. No separate support sleeves are required around the permanent magnet. The axle practically consists of only two parts interconnected by sufficiently long threads, so assembling of the axle is very simple and quick. No special tools are required to assemble the axle. Further, the structure allows implementation of a very simple plate transmitting the magnetic force of the axial bearing in the axle. In addition, the length of the active part of the rotor can be modified by changing only one of the parts of the axle.

BRIEF DESCRIPTION OF THE DRAWINGS

Below, the invention will be described in detail with reference to the accompanying drawing illustrating one rotor axle of a high speed permanent magnet machine according to the invention as a partial sectional view.

DETAILED DESCRIPTION OF THE INVENTION

The figure illustrates one rotor axle of a high speed permanent magnet machine according to the invention consisting mainly of two concentric parts interconnected substantially one after the other, namely a first part 1 and a second part 2. The parts are cylindrical objects which are symmetrical relative to the central axis.

The inner end of the first part 1 includes an external thread 4, following which the external surface of the first part has a radial and annular circumferential

surface, i.e. a shoulder 8. Then, the first part has the radial magnetic bearing structures 11 necessary for the axle. A central hole 10 opens at the outer end of the first part 1 and extends through the entire
5 part.

The inner end of the second part 2 includes a cylinder sleeve 5 having a cylindrical base part 6 corresponding relatively accurately in shape to the shape of the
10 cylindrical permanent magnet 3 used. This way, the permanent magnet can be tightly placed in this base part so as to be substantially backlash-free. Towards the inner end from the space required by the permanent magnet 3, the cylinder sleeve 5 in the second part in-
15 cludes an internal thread 7 corresponding to the external thread 4 of the inner end of the first part 1. This way, the first part 1 and the second part 2 can be rotated together one after the other by the corresponding threads to constitute a concentric structure.
20 In addition, the outer end of the second part 2 has corresponding radial magnetic bearing structures 11 necessary for the axle and a hole 10 opening at the outer end and centrally extending through the second part up to the base part 6, i.e. to the magnet 3
25 therein.

The peripheral edge of the cylinder sleeve 5 of the second part 2 is a straight and planar annular surface, and a space is formed between it and the corresponding straight annular surface of the shoulder 8
30 for accommodating a ring-shaped disc 9. Its thickness is so adapted that it becomes firmly tightened in its position when the first part 1 and the second part 2 are screwed together.

In assembling the rotor axle, the magnet 3 can just be inserted into the second part 2 against the base part 6. Not even a tight fit should prevent the insertion of the magnet because air is able to flow out through
5 the central hole 10 of the second part. In the same way, the magnet can be removed from its position as needed by pushing through the hole.

Normally, the permanent magnet is pressed in its space
10 between the first part and the second part. However, should it be necessary to fix the magnet even more tightly, this can be accomplished through the central hole 10 of the first part for example by providing a thread in the inner part of the hole 10 close to the
15 magnet 3. Through the hole, a suitable screw can be rotated on the thread so as to press the magnet and thus lock it in its position.

The invention has been described above by way of exam-
20 ple with reference to the accompanying drawing; however, different embodiments of the invention are possible within the scope defined by the claims.

CLAIMS

1. A rotor axle of a high speed permanent magnet machine including a first part (1) and a second part
5 (2), both manufactured from a magnetically non-conducting material and including an inner end and an outer end for being axially interconnected one after the other by the inner ends to constitute an integral rotor axle, the outer ends including bearing structures (11) to fit the rotor axle with bearings, and a
10 cylindrical and solid permanent magnet (3) which is coaxial with the first part and the second part in between them and magnetized perpendicularly to the axial direction of the cylinder, characterized in that the inner end of the first part (1) of the rotor axle includes a cylindrical external surface with an external thread (4) and that the inner end of the second part (2) includes a cylinder sleeve (5), of which the internal base part (6) corresponds in shape to the
15 cylindrical permanent magnet (3) so as to constitute a space for the permanent magnet, and of which the internal lining has an internal thread (7) corresponding to the external thread of the first part, so that when the first part and the second part are concentrically
20 rotated together one after the other in the axial direction, the permanent magnet (3) is provided in its space between the parts.

2. The rotor axle according to claim 1, characterized in that the first part (1) and the second
30 part (2) are made of metal, such as steel, for example stainless steel.

3. The rotor axle according to claim 1, characterized in that the first part (1) and the second
35 part (2) are made of titanium.

4. The rotor axle according to claim 1, characterized in that the first part (1) and the second part (2) are made of a composite suitable for the purpose.

5. The rotor axle according to any one of claims 1-4, characterized in that the bearing structures (11) include conical surfaces acting as bearing surfaces in axial and radial bearings.

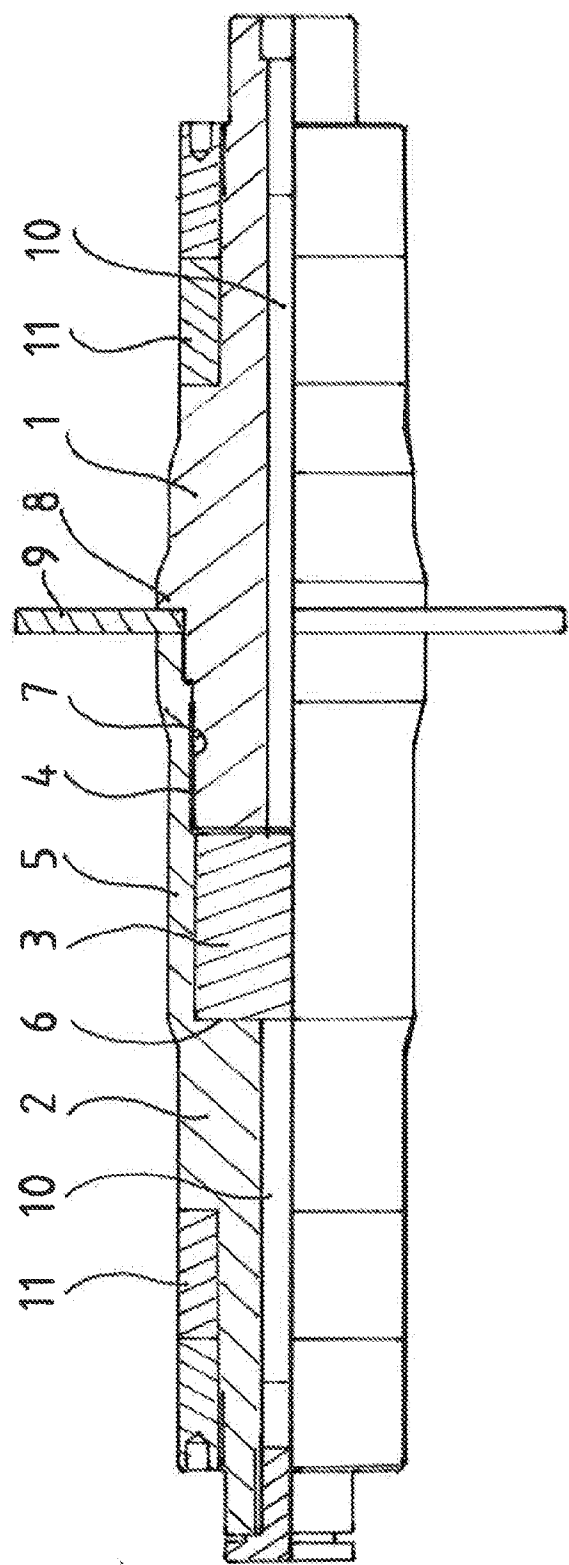
6. The rotor axle according to any one of claims 1-4, characterized in that the first part (1) includes a radial shoulder (8), whereby an annular space is provided between it and the peripheral edge of the cylinder sleeve (5) of the second part (2), in which space an annular disc (9) can be placed and pressed in its position between the parts by rotating the first part and the second part together.

7. The rotor axle according to claim 6, characterized in that the annular disc (9) is a plate transmitting the magnetic force of the axial bearing, a fan or a combination thereof.

8. The rotor axle according to claim 6 or 7, characterized in that the surface of the annular disc (9) includes substantially radial grooves or channels to provide cooling air flows.

9. The rotor axle according to any one of claims 1-8, characterized in that the first part (1) and the second part (2) are hollow objects provided with a central hole (10).

10. The rotor axle according to any one of claims 1-9,
characterized in that the rotor axle includes
an alternative second part, wherein the internal base
part corresponds in shape to a cylindrical permanent
5 magnet of an alternative size so as to constitute a
space for the alternative permanent magnet.



INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2013/051103

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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)

IPC: H02K, F01D

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

FI, SE, NO, DK

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

EPO-Internal, WPI, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011304234 A1 (RAMON DAVID [CH] et al.) 15 December 2011 (15.12.2011)	1-5, 9-10
Y	par. [0001], [0006], [0024], [0026]; figs. 2, 4	6-8
X	US 2005134132 A1 (PRUYN KRISTOPHER [US]) 23 June 2005 (23.06.2005)	1-5, 9-10
Y	par. [0002]-[0003], [0022]-[0023], [0025]; figs. 1-6	6-8
Y	EP 0313310 A2 (SATAKE ENG CO LTD [JP]) 26 April 1989 (26.04.1989)	6-8
A	abstract; col. 5, lines 21-47, col. 11, lines 22-36; figs. 1-12	1-5, 9-10
A	JP 2009022096 A (ASMO CO LTD) 29 January 2009 (29.01.2009) figs. 1-7 & abstract [online] EPOQUENET EPODOC & WPI & machine translation into English by Thomson Scientific [online] EPOQUENET TXTJPT par. [0004], [0031]-[0032], [0048], [0050], [0052]-[0053]	1-10

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 March 2014 (25.03.2014)

Date of mailing of the international search report

26 March 2014 (26.03.2014)

Name and mailing address of the ISA/FI
Finnish Patent and Registration Office
P.O. Box 1160, FI-00101 HELSINKI, Finland

Facsimile No. +358 9 6939 5328

Authorized officer

Ville Möttönen

Telephone No. +358 9 6939 500

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2013/051103

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP H02123939 A (ISUZU MOTORS LTD) 11 May 1990 (11.05.1990) figs. 1-8 & abstract [online] EPOQUENET EPODOC & WPI	1-10
A	US 6047461 A (MIURA HARUO [JP] et al.) 11 April 2000 (11.04.2000) the whole document	1-10
E	WO 2014003563 A1 (MICRO TURBINE TECHNOLOGY BV [NL]) 03 January 2014 (03.01.2014) the whole document	1-10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2013/051103

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.

H02K 1/27 (2006.01)

H02K 1/28 (2006.01)

H02K 21/12 (2006.01)

H02K 9/06 (2006.01)

F01D 5/02 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2013/051103

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2011304234 A1	15/12/2011	CN 102290893 A	21/12/2011
		DE 102010023813 A1	15/12/2011
		EP 2398130 A2	21/12/2011
		KR 20110136756 A	21/12/2011
		US 8569920 B2	29/10/2013
US 2005134132 A1	23/06/2005	US 7262535 B2	28/08/2007
		WO 2005064775 A1	14/07/2005
EP 0313310 A2	26/04/1989	AU 2395888 A	20/04/1989
		AU 2396088 A	20/04/1989
		CN 1032717 A	03/05/1989
		CN 1032718 A	03/05/1989
		DK 581388 D0	19/10/1988
		DK 581388 A	21/04/1989
		DK 581488 D0	19/10/1988
		DK 581488 A	21/04/1989
		EP 0313309 A2	26/04/1989
		FI 884817 A	21/04/1989
		FI 884818 A	21/04/1989
		JP H01107636 A	25/04/1989
		JP H01110089 A	26/04/1989
		JP H01231637 A	14/09/1989
		JP H01255498 A	12/10/1989
		JP H01283093 A	14/11/1989
		NO 884567 D0	13/10/1988
		NO 884567 A	21/04/1989
		NO 884568 D0	13/10/1988
		NO 884568 A	21/04/1989
JP 2009022096 A	29/01/2009	None	
JP H02123939 A	11/05/1990	None	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2013/051103

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 6047461 A	11/04/2000	CN 1211100 A	17/03/1999
		CN 1106065 C	16/04/2003
		FR 2768271 A1	12/03/1999
		FR 2768271 B1	10/11/2000
		JP H1189142 A	30/03/1999
		JP 3484051 B2	06/01/2004
WO 2014003563 A1	03/01/2014	None	