

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
10 May 2002 (10.05.2002)

PCT

(10) International Publication Number  
WO 02/037643 A3

(51) International Patent Classification<sup>7</sup>: H02K 29/03, 1/27

(21) International Application Number: PCT/US01/47293

(22) International Filing Date: 30 October 2001 (30.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
09/704,183 1 November 2000 (01.11.2000) US

(71) Applicant: EMERSON ELECTRIC CO. [US/US]; 8000 West Florissant Ave., St. Louis, MO 63136 (US).

(72) Inventors: WALLS, Todd; 1053 Raritan, Rock Hill, MO 63119 (US). CRAPO, Alan; 16716 Jamestown Forest Drive, Florissant, MO 63034 (US).

(74) Agent: WIGGINS, Michael, D.; Harness, Dickey & Pierce, P.L.C., P.O. Box 828, Bloomfield Hills, MI 48303 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

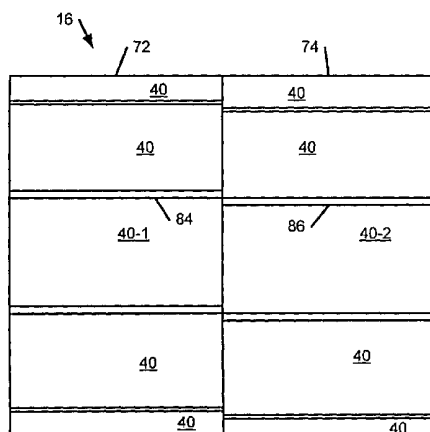
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**  
— with international search report  
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(88) Date of publication of the international search report:  
10 October 2002

[Continued on next page]

(54) Title: PERMANENT MAGNET ELECTRIC MACHINE HAVING REDUCED COGGING TORQUE



(57) Abstract: A permanent magnet electric machine includes a stator with salient stator poles. A rotor (16) includes two or more axial rotor sections (72,74) that are rotationally offset by an offset angle equal to the cogging angle divided by the number of axial rotor sections. The axial rotor sections include rotor poles with permanent magnets (40). In one embodiment, the permanent magnet electric machine has a 12/10 slot/pole combination. The permanent magnets have a magnet dimension angle between 31 and 35 degrees. An air gap ratio of the electric machine is between 1.35 and 2.5. A slot opening ratio of the electric machine is less than or equal to one. In another embodiment, the permanent magnet electric machine has an 18/12 slot/pole combination. The permanent magnets have a magnet dimension angle that is between 25 and 28 degrees. An air gap ratio of the electric machine is between 1.35 and 2.5. A slot opening ratio of the electric machine is less than or equal to one.



WO 02/037643 A3



---

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## INTERNATIONAL SEARCH REPORT

 Internat Application No  
 PCT/US 01/47293

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H02K29/03 H02K1/27

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)

IPC 7 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)

PAJ, EPO-Internal, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 031 (E-475), 29 January 1987 (1987-01-29) -& JP 61 199447 A (MITSUBISHI CHEM IND LTD;OTHERS: 01), 3 September 1986 (1986-09-03)	1
Y	abstract; figures 1,2 ---	2,4,9,13
X	EP 0 300 042 A (FANUC LTD) 25 January 1989 (1989-01-25) abstract; figures 1-3 page 1, line 24 -page 2, line 4 ---	1
Y	US 6 034 460 A (KAWAMATA SHOUICHI ET AL) 7 March 2000 (2000-03-07) figure 2 ---	2,4
	-/--	

 Further documents are listed in the continuation of box C. Patent family members are listed in 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 document 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

8 August 2002

Date of mailing of the international search report

21/08/2002

Name and mailing address of the ISA

 European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
 Fax: (+31-70) 340-3016

Authorized officer

Contreras Sampayo, J

## INTERNATIONAL SEARCH REPORT

 International Application No  
 PCT/US 01/47293

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 449 538 A (LUCAS IND PLC) 2 October 1991 (1991-10-02) figure 2 ---	9,13
A	EP 0 564 759 A (MORRILL GILES W) 13 October 1993 (1993-10-13) abstract; figures 2,5 ---	7,11,16, 18,22,24
A	US 5 397 951 A (UCHIDA HIROYUKI ET AL) 14 March 1995 (1995-03-14)  figures 1B,8 ---	3,5,6, 10,14, 15,21
A	ACKERMANN B ET AL: "New technique for reducing cogging torque in a class of brushless DC motors" IEE PROCEEDINGS B (ELECTRIC POWER APPLICATIONS), JULY 1992, UK, vol. 139, no. 4, pages 315-320, XP002209198 ISSN: 0143-7038 abstract page 315, column 2 page 316, column 1 ---	
A	CHEN S X ET AL: "THE ROBUST DESIGN APPROACH FOR REDUCING COGGING TORQUE IN PERMANENT MAGNET MOTORS" IEEE TRANSACTIONS ON MAGNETICS, IEEE INC. NEW YORK, US, vol. 34, no. 4, PART 1, July 1998 (1998-07), pages 2135-2137, XP000833296 ISSN: 0018-9464 abstract; tables I,II -----	

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 01/47293

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 61199447	A	03-09-1986	JP 2552824 B2	13-11-1996
EP 0300042	A	25-01-1989	JP 63178750 A	22-07-1988
			DE 3873441 D1	10-09-1992
			DE 3873441 T2	21-01-1993
			EP 0300042 A1	25-01-1989
			WO 8805617 A1	28-07-1988
			US 5039897 A	13-08-1991
US 6034460	A	07-03-2000	JP 9285088 A	31-10-1997
			US 6396183 B1	28-05-2002
EP 0449538	A	02-10-1991	EP 0449538 A1	02-10-1991
EP 0564759	A	13-10-1993	US 5260620 A	09-11-1993
			AU 2961292 A	16-09-1993
			CA 2083974 A1	10-09-1993
			DE 69303956 D1	19-09-1996
			DE 69303956 T2	06-03-1997
			EP 0564759 A1	13-10-1993
US 5397951	A	14-03-1995	JP 5161287 A	25-06-1993
			DE 69216587 D1	20-02-1997
			DE 69216587 T2	10-07-1997
			EP 0569594 A1	18-11-1993
			WO 9311596 A1	10-06-1993
			KR 132516 B1	20-04-1998