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Nutation motor : a new direct-drive stepping motor for robots

Koichi Suzumori* Takefumi Kanda†

Kazuo Uzuka‡ Isao Enomoto**

*Okayama University

†Okayama University

‡TOK Bearings Corporation Limited

**TOK Bearings Corporation Limited

NUTATION MOTOR
-- A New Direct-drive Stepping Motor for Robots --

Koichi Suzumori [1], Takefumi Kanda [1],
Kazuo Uzuka [2], Isao Enomoto [2]
[1] Okayama University,
Okayama, Japan, suzumori@sys.okayama-u.ac.jp
[2] TOK Bearings Co. LTD., Tokyo, Japan

Abstract---A new type of stepping motor, named nutation motor was developed. This motor has a reduction mechanism consisting of a pair of bevel gears, realizing high torque and high resolution stepping motion. Three prototypes, two pneumatic nutation motors and an electric nutation motor, were designed, developed, and tested. We show the basic driving principle and the experimental results in this paper.

Keywords --- Actuator, Motor, Reduction gear
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1. INTRODUCTION

Combining reduction gears and a motor produces a compact actuators with high torque [1],[2]. The aim of this research is to develop a new stepping motor which has reduction mechanism, resulting in high torque and compact mechanism. A reduction mechanism consisting of a pair of bevel gears is used in our design. We have developed three types of nutation motor based on this design.

2. DRIVING PRINCIPLE

Figure 1 shows a basic driving principle of nutation motor. Nutation motor consists of a pair of bevel gears; a cone-shaped bevel gear, named nutator and a cup-shaped bevel gear, named rotor. While the rotor is supported by bearings, the nutator is supported by a spherical bearing and guide pins, allowing its nutation as shown in Fig. 1. As the bevel gears have different numbers of tooth, nutation of the nutator causes rotation of the rotor.

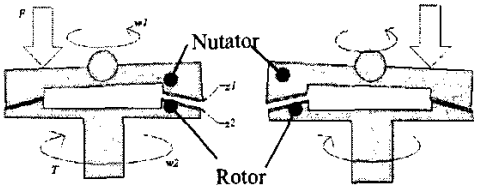

Figure 1 A basic driving principle of nutation motor

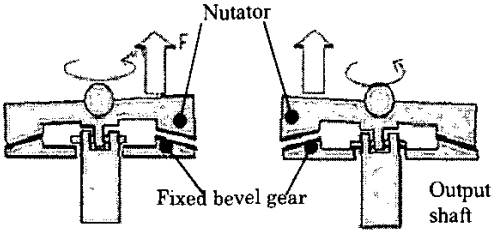

Figure 2 A variation of nutation motor

The nutator is driven by pneumatic cylinders or electric solenoids set behind the nutator. Fig. 1 shows an example of a pneumatic nutation motor, in which a pneumatic cylinders push on the nutator sequentially as shown the arrows in Fig.1.

We have several variations of this nutation mechanism. Figure 2 shows another example. The output shaft is connected to the nutator with a universal joint in this design. Nutation motion of the nutator, which is caused by electromagnetic force shown in the arrows,

Table1 Motor specifications

	Pneumatic motor	Micro pneumatic motor	Electric motor
Size [mm]	ϕ 50 × 49	ϕ 10 × 16.7	50 × 50 × 70
Weight [g]	650	880	880
Numbers of tooth	121 for nutator 120 for rotor	30 for rotary bevel gear 29 for fixed bevel gear	156 for rotary bevel gear 155 for fixed bevel gear
Torque [Nm]	2 max.	5.5×10^{-3} max.	0.64max.
Speed [rpm]	10 max.	40max.	4.3max.
Step angle [deg]	0.5	4	0.3

results in the rotation of the shaft.

3. PROTOTYPES AND EXPERIMENTS

Three prototypes are shown in this report; a pneumatic nutation motor[3], a micro pneumatic nutation motor, and an electric nutation motor[4].

Figures 3, 4, and 5 show the cross-section of each motor. Figure 6 shows an interior of the pneumatic nutation motor. Table 1 shows the specifications and experimental characteristics of each motor.

The reduction gear structure of the pneumatic motor shown in Fig. 3 is based on the mechanism shown in Fig.1. The nutator is driven by three pneumatic cylinders built in the motor housing.

The micro pneumatic motor shown in Fig. 4 is 10 mm in diameter. It has a rubber diaphragm which has three convex pneumatic rooms. Applying air pressure to each chamber sequentially causes sequential elastic deformation of the diaphragm, resulting in the nutation of the nutator. Meshing of the nutator bevel gear and the fixed bevel causes rotation of the nutator. The rotation of the nutator is transmitted to the output shaft through output bevel gears as shown in Fig. 4.

The electric motor shown in Fig. 5 consists of six solenoid coils. The reduction mechanism is based on the mechanism shown in Fig.2.

4. CONCLUSIONS

We proposed a new stepping motor, named nutation motor. Three prototypes are developed and their mechanism and characteristics are shown in this report. The motor realizes high torque and has a great potential as a new direct-drive stepping motor for robots.

REFERENCES

[1] K.Suzumori, K.Hori, and T. Miyagawa, A Direct-Drive Pneumatic Stepping Motor for Robots: Designs for Pipe-Inspection Microrobots and for Human-Care Robots, *Proc. IEEE International. Conf. on Robotics and Automation*, (1998), pp.3047-3052.

[2] H.Kimura, S.Hirose, and K. Nakaya, Development of the Crown Motor, Proc. ICRA, Seoul, pp.2442-2447 (2001).

[3] T.Nagata, K.Suzumori, T.Kanda, K.Uzuka and I. Enomoto, Electro Direct-Drive Stepping Motor for Robots, *Proc. IEEE International Conference on Robotics and Automation*, pp.4493-4498, (2004-4)

[4] K.Suzumori, T.Nagata, T.Kanda, K.Uzuka, and I. Enomoto, Development of Electromagnetic Nutation Motor (Electromagnetic Investigation), *Journal of Robotics and Mechatronics*, Vol.16, No.3, pp.327-332, (2004-6).

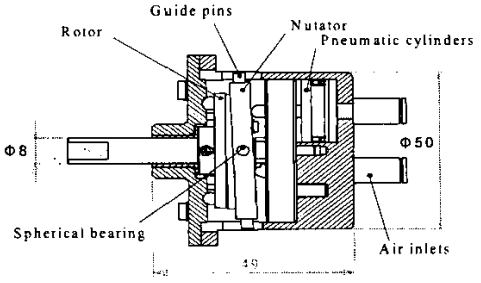

Figure 3 Pneumatic nutation motor

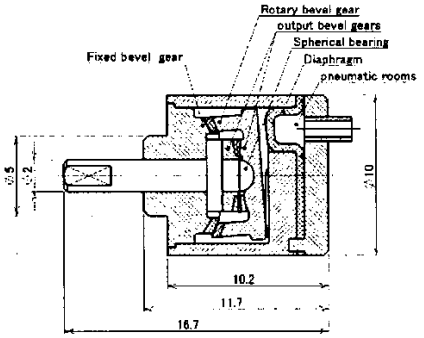

Figure 4 Micro pneumatic motor

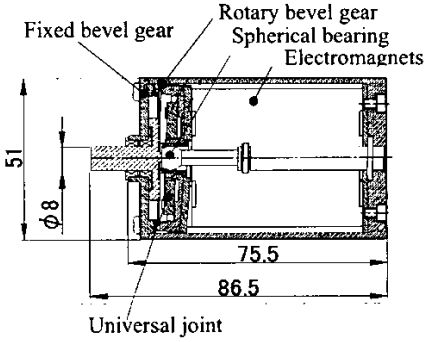

Figure 5 Electric nutation motor

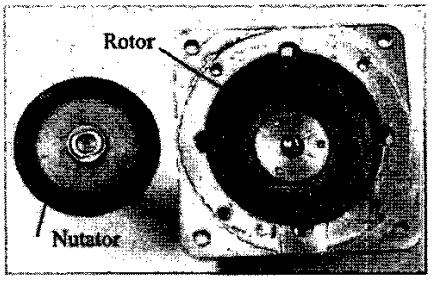

Fig.6 Nutator and rotor