Design of Coreless PM motor with non-magnetic tooth-slot structures using 3D printing technology

Dong-hoon Jung[1], Hyunwoo Kim[1], Seungheon Lee[1], Ju Lee[1]

1. University of Hanyang, 222, Wangsimni-ro, Seongdong-gu, Seoul, South Korea

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Background

It is necessary to develop a motor with high output density, high efficiency, and high control accuracy in various industries like automobiles, robots and defense industry. Among the various types of motors, Slotless permanent magnet (PM) motors having relatively structural and electromagnetic advantages over slotted motors have been continuously developed for the precise control as a driving and servo motor. However, since the slotless motor has no tooth and corresponding slots, it requires a complex winding method, applied the skew, to maintain the structure of windings so that it makes the production process complicated and requires a lot of time and money. In this paper, design method of coreless PM motor with non-magnetic tooth-slot structures using 3D printing technology, which can replace the conventional slotless motor, is proposed.

Conclusion

- ❖ BLDC coreless PM motor is designed using non-magnetic tooth-slot structures printed using 3-D printer
- ❖ Electromagnetic output characteristics are analyzed and compared with the conventional slotless PM motor
- ❖ The effective design method of BLDC coreless PM motor using 3-D printing which provides the reliability and convenience of the design and fabrication by getting out of the winding methods of the conventional slot-less motor is proposed.

Design of BLDC coreless PM motor

Introduction & Design of Coreless PM motor

❖ **Advantages of slotless PM motor :** no teeth and their corresponding slots

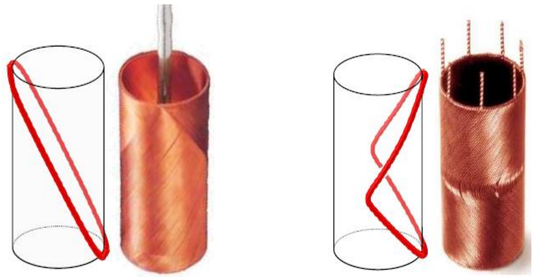
* No cogging torque * Low torque ripple * Low iron loss

* Even at the highest currents the produced torque is proportional to the motor current.

* No saturation effects in the iron core * Less vibrations and audible noise

❖ **Winding methods of conventional slotless PM motor :**

(1) Faulhaber (called skewed-winding) (2) Rhombic winding (3) Diamond winding



Conventional winding method of slotless PM motor
: skewed-winding, Rhombic winding

❖ **Design Spec. & Constraints of coreless PM motor**

* Compact size : Coreless PM motor designed in this paper requires rapid response for reverse rotation ➔ Small size of rotor (Low rotor inertia)

Spec. & Constraint of Coreless PM motor

Content	Value	Unit
Rated Speed	5,000	rpm
Power	18.5	W
Voltage limit	35	V_{dc}
Current limit	1.5	A_{peak}
Size	30Φ ×50	mm

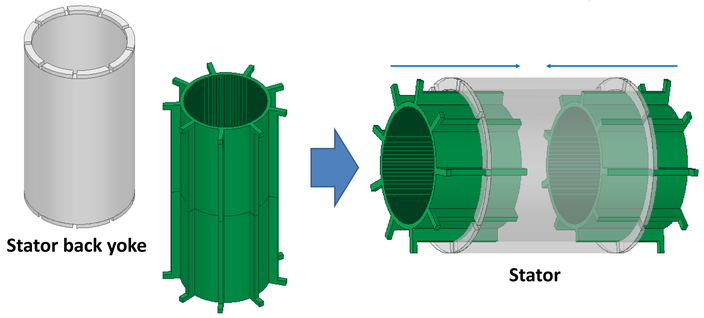
❖ **Problems of conventional slotless PM motor**

* It uses the skew to their windings to fabricate and maintain their winding structure

➔ Complicated fabrication & process + negative effects on the electromagnetic output characteristics + high manufacturing tolerance

❖ **Proposed design method : Coreless PM motor with non-magnetic tooth-slot structures printed using 3D printer**

➔ **Take advantages of slotless PM motor without complicated winding structure**



Stator of BLDC coreless pm motor
(Stator back yoke + 3D printing structure

❖ Selection of 3D printing material

* 3D printing material : PC(Poly carbonates) ➔ Small printing tolerance

Characteristics of 3D printing material

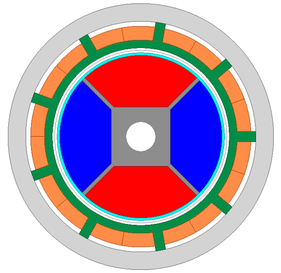
Content	Deformation temperature [°C]	Tensile strength [Mpa]
ABS	96	33~36
PC	133~138	57~58
PEI(Ultem)	167~216	72~81

Design & Final model of BLDC coreless PM motor

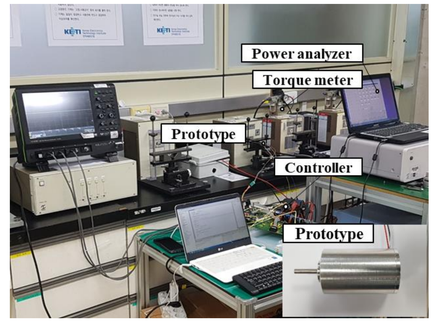
❖ **Comparison of electromagnetic output characteristics**

* Conventional slotless PM motor and BLDC coreless PM motor with 3D printing teeth-slot structure have the same size, structure and material of rotor

* BLDC coreless PM motor has much higher power density (about 25 %) with electromagnetic advantages of the conventional slotless PM motor



BLDC coreless PM motor
With 3D Printing structure



Spec. & Constraint of Coreless PM motor

Content	Conventional slotless PM motor	BLDC coreless PM motor	Unit
Rated Speed	5,000		rpm
Voltage	24	26	V_{dc}
Current	0.96	0.94	A_{peak}
Torque constant	73.91	93.48	mNm/A
Power density	1.89	2.39	W/cm^3

Result of Experimental test with prototype

Content	FEA	Experimental test	Unit
Noload-back EMF	24.53(17.5)	24.75(17.5)	V
Error	0.9		%