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Structure and Electromagnetic Characteristics according to Pole-piece Supporter Material of Magnetic Gear

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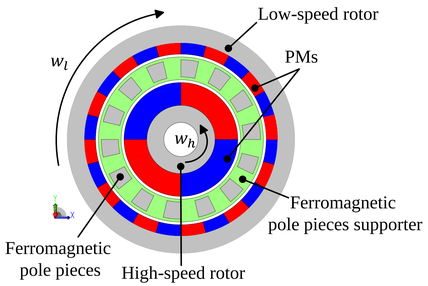
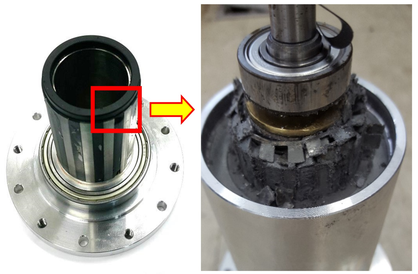
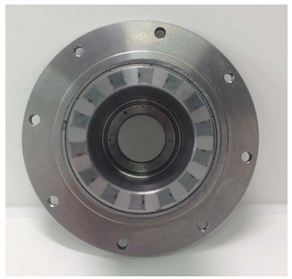
Abstract—Studies on coaxial magnetic gears (CMG) have been actively conducted. CMGs can replace mechanical gears as they can perform noncontact power transfer, thereby minimizing loss and damage from friction. In the design stage of CMG, 2D electromagnetic finite element analysis (FEA), which is highly reliable and save cost, is widely used. However, during prototyping and testing in the review phase, the prototype's pull-out torque is lower than the pull-out torque predicted from 2D electromagnetic FEA and could be up to 30% different. One of opinions raised about this phenomenon is that the torsional stiffness of the pole-piece part structure is low thereby the electrical angle is skewed. There are high frequency magnetic fluxes in the pole-piece part. This is an area where magnetic losses are expected to be high. In many studies, non-metal pole-piece supporter which can minimize the magnetic loss was applied. The disagreement between analysis and experiment was shown but no one study it in detail. In this paper, metal pole-piece supporter is used to remove the torsion possibility. 3D-FEA and experiment are compared and an opinion of analysis reliability by the torsion is shown. In addition, the magnetic loss on metal supporter is analyzed in detail.

Structure of The Pole piece Supporter





<Non-metal supporter-epoxy>



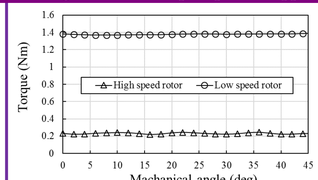
<Metal supporter-SUS304>

<Structural characteristics of the Pole piece>

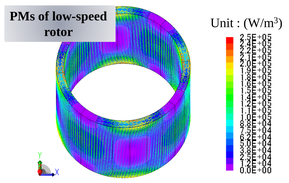
- The PP (Pole Piece) is subjected to time-varying magnetic fields, a laminated core is used to reduce the eddy current loss
- The laminated PP requires a separate supporting mechanism, since it also has to serve as a mechanical earth for supporting the CMG.
- If material of the PP supporter has a low torsional stiffness, a microscopic twist is generated by torque of rotors, and the electric angle fluctuates to cause torque reduction. This is fatal to low speed rotors with a large number of poles.

Index		Pole Piece Supporter Material	
		non-magnetic material	SUS material
Torque ratio		5.95	5.8
Torque transfer efficiency (%)		98.95	96.51
Torque	Inner rotor (Nm)	0.23	0.23
	Inner rotor ripple (%)	11.64	11.8
	Outer rotor (Nm)	1.38	1.34
	Outer rotor ripple (%)	2.81	2.99
Power	Inner rotor (W)	14.58	14.52
	Outer rotor (W)	14.46	14.05
Loss	PMs eddy current loss (W)	0.11	0.11
	Pole piece supporter eddy current loss (W)	-	0.36
	Iron loss (W)	0.039	0.039

non-magnetic material pole pieces supporter

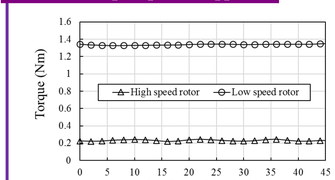


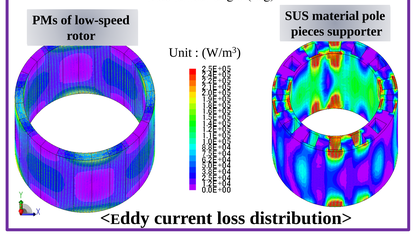
<Torque waveform>



<Eddy current loss distribution>

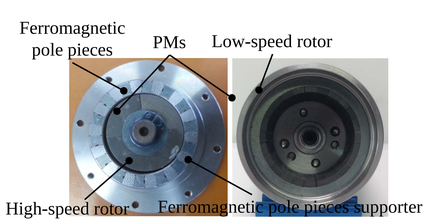
SUS material pole pieces supporter



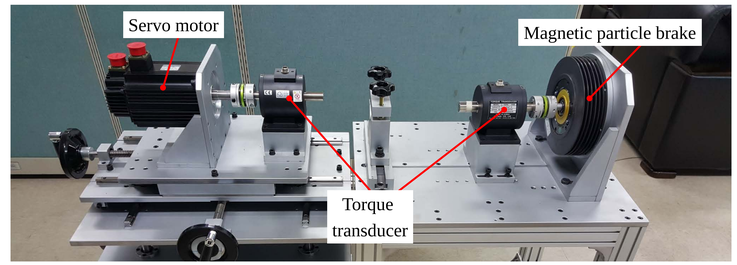


<Eddy current loss distribution>

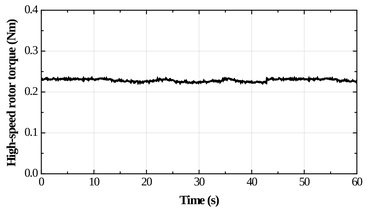
Prototype and Experiment

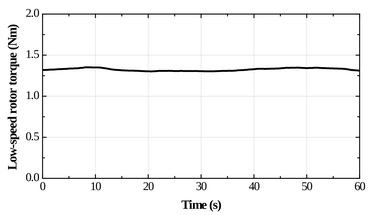


<Prototype magnetic gear>



<Experimental setup>

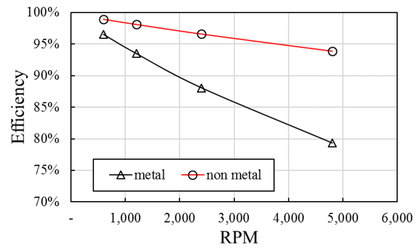




- High speed rotor : 0.23 Nm, 0.5% low
- Low speed rotor : 1.32 Nm, 1.5% low
- Almost same with 3D FEA

This may be due to removing the torsional effects mentioned in other papers. However, even in 2D and 3D comparisons, the difference is so small compared to other papers that it cannot be concluded that this is due to the torsional effect. Rather, it is important to realize the design conditions of the prototype as FEA through various measurements and to use high quality mesh.

Loss of Metal Supporter



<Torque ratio and transfer efficiency to the rotation speed>

<Loss comparison according to the rotation speed>

Index		Pole Piece Supporter Material	
		non-magnetic material	SUS material
1200 rpm	PMs eddy current loss (W)	0.45	0.44
	Pole piece supporter eddy current loss (W)	-	1.41
	Iron loss (W)	0.10	0.010
2400 rpm	PMs eddy current loss (W)	1.77	1.75
	Pole piece supporter eddy current loss (W)	-	5.57
	Iron loss (W)	0.24	0.23
4800rpm	PMs eddy current loss (W)	6.84	6.69
	Pole piece supporter eddy current loss (W)	-	21.50
	Iron loss (W)	0.57	0.56

In this paper, we tried to improve the analytical reliability for the problem that the experimental torque of the magnetic gear is lower than the FEA result. The pole piece supporter was designed to prevent the twist of the pole piece and the 3-D FEA is used considering the leakage flux. The analysis results were compared with the experimental results. Experimental results show that the torque of the magnetic gear is almost same with the analytical value.

By using the pole piece supporter made of SUS, although assuming the effect of twisting of the pole piece can be eliminated, there is a problem of eddy current loss occurring in the pole piece supporter. Therefore, in design of the magnetic gear, the applications must be considered.

When a weak supporter is used, it is advantageous for high-speed driving due to low eddy current loss, but it is required to be used in a high-speed low-torque application due to a problem of supporter breakage. It can be applied to high-grade vehicles and robots that require quietness, with an advantages of low-noise driving of magnetic gears. On the other hand, when using a material with a strong as a supporter, it is necessary to use it in low-speed drive applications because there is a large risk of eddy current loss. Also, low-speed and high-torque applications is suited because there is less concern about supporter breakage. Therefore, it can be applied to the machine field where the mechanical gear is damageable.