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A Design of Outer Yoke and Enclosure Considering Magnet Eddy Current Loss of Magnetic Gear

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Abstract

The magnetic gear is free from wear, noise, and vibration problems because it uses magnetic coupling to transmit power and has no mechanical contact; however, it incurs losses owing to magnetic coupling. This paper suggests a method for reducing the permanent magnet eddy current loss, which is one of the magnetic losses. First, a harmonic analysis is performed to analyze the factors affecting the permanent magnet eddy current loss and the factors affecting the output. Then, a core structure capable of reducing only loss-related harmonics is proposed. The proposed structure improves efficiency by maintaining output-related harmonics and reducing loss at the same output.

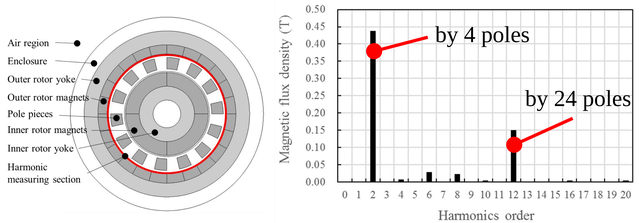
Key words – Harmonic analysis, Magnet eddy current loss, Magnetic gear, Enclosure loss, Flux leakage

Conclusion

- A harmonic analysis revealed that the 2nd harmonic component affecting the loss permeated the permanent magnet, to a large extent owing to the low magnetic resistance, and this caused the loss.
- To reduce the loss-causing component, the magnetic resistance was increased by adjusting the thickness of the iron core and the magnetic flux of the loss component was leaked by forcibly saturating the core.
- As a result, the harmonic causing loss decreased by 20.5%, the eddy current loss of the outer permanent magnet declined by 36.7%, and the outer core loss was reduced by 12.9%. The total efficiency reached 98.6%, which was 2.8% higher than its previous value.
- The method proposed in this study could result in an additional loss if the enclosure is made of a conductive material, because it has a magnetic flux component that is leaked owing to the low thickness of the iron core. Therefore, the enclosure must be made of a nonconductive material to produce the loss reduction effect by applying the proposed method.

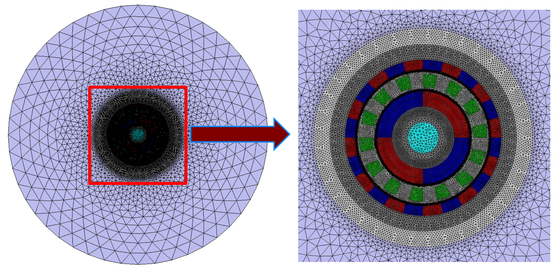
Model and Condition

Basic model: 4/24 Poles, 14Pole pieces



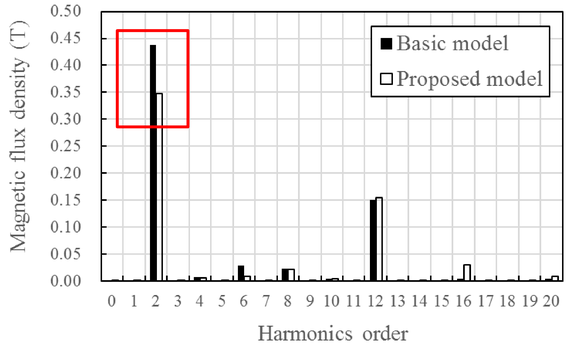
Inner revolution speed	12,000 rpm	Magnet eddy loss (In/Out)	5 W/ 86 W
Outer revolution speed	2,000 rpm	Iron loss (In/Out/PP)	0.2mW/ 47W/ 7.5W
Inner torque/Power	2.73 Nm / 3,429 W	Efficiency	95.8 %
Outer torque/Power	15.95 Nm / 3,340 W	Gear ratio	6 : 1

Analysis Mesh Condition



Elements: 46,810 / Nodes: 27,750 / Air region: 3 times of model length

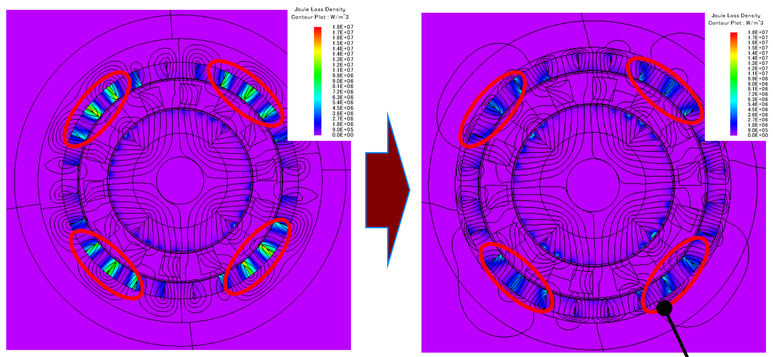
Harmonic Analysis Result



- The outer rotor core of the basic model is 6 mm thick. The characteristics of this model were analyzed by adjusting the thicknesses, and the best results were obtained at the 1.2 mm core thickness.
- The 2nd harmonic component affecting loss was 0.35 T, which was lower **by 20.5%** compared to 0.44 T of the basic model.
- The 12th harmonic affecting the output was 0.15 T, identical for both models.
- The output was identical at 3.3 kW and the efficiency was **98.6%**, 2.8% higher than that of the basic model.

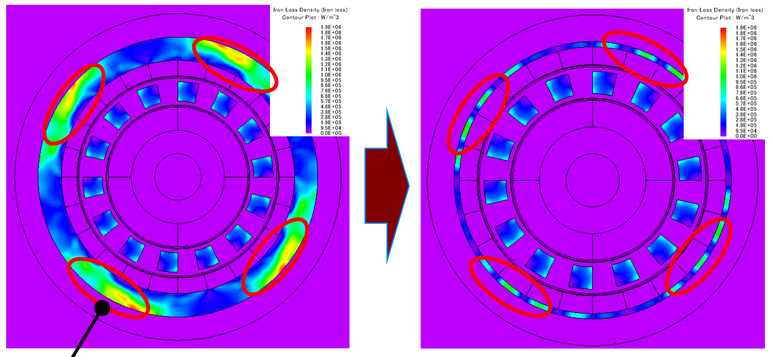
Results

Magnet Eddy Current Loss Contour and Flux line



86W => 32W, **36.7%** reduction

Iron Loss Contour

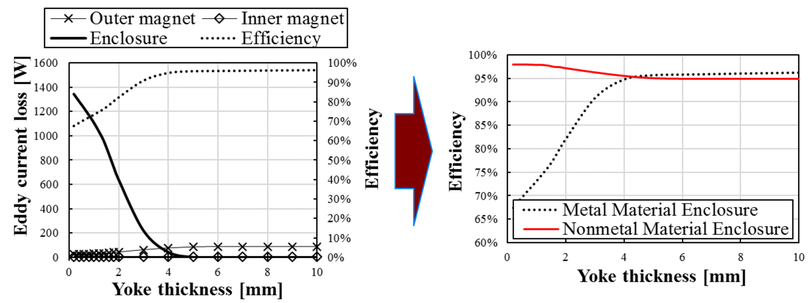


46.97W => 6.06W, **12.9%** reduction

Loss by the 2nd harmonic

Leakage Flux Effect

The result of applying SUS304 for the enclosure material of the proposed model



At the yoke thickness of 1.2 mm suggested in this study, there were no changes in the permanent magnet eddy current loss or the iron core loss, but a greater loss occurred in the enclosure.

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