

Analysis of Torque Characteristics According to Gear ratio of Coaxial Magnetic Gear

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Abstract

In this paper, the analysis of the pull-out torque and torque total harmonic distortion (THD) characteristics according to the gear ratio of the magnetic gear was performed through the two-dimensional finite element analysis method. In addition, the transient analysis according to the gear ratio using the torque obtained from the pull-out analysis was carried out to analyze the torque and torque ripple of the transient analysis and the characteristics of the outer rotation speed. The results of the analysis show how torque THD and torque ripple affect the magnetic gear according to the gear ratio.

Analytical Model of a Magnetic Gear

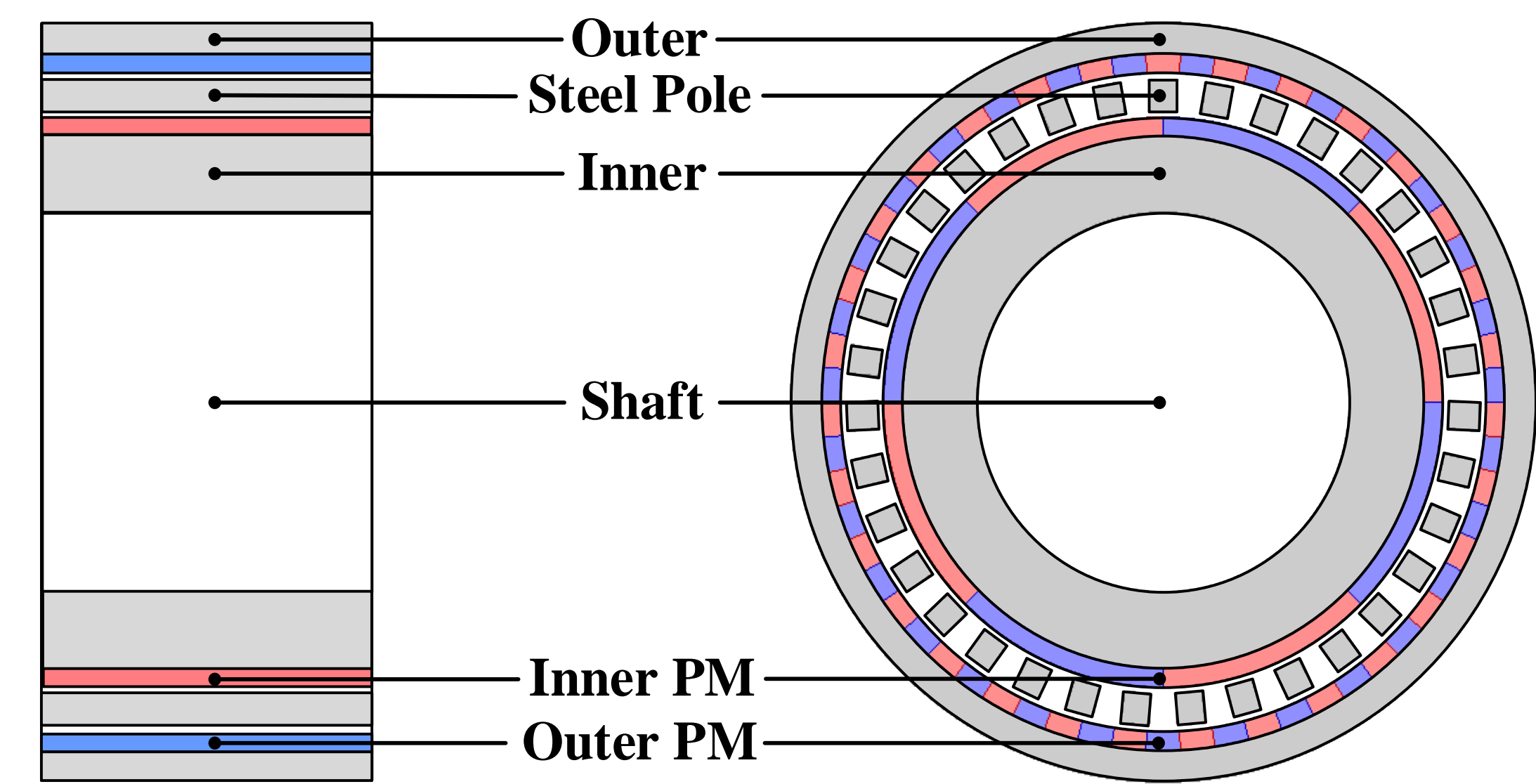


Fig. 1. Structure of magnetic gear

Table 1. Design specifications for magnetic gear

Parameter	Value	Unit
Outer radius of outer rotor	60	mm
Inner radius of outer rotor	55	mm
Outer radius of inner rotor	42	mm
Inner radius of inner rotor	30	mm
Steel-Pole thickness	5	mm
Stack length	70	mm
Inner / Outer Permanent magnet thickness	3 / 3	mm
Inner / Outer Air gap	1 / 1	mm
Inner speed	1000	rpm

- ✓ Fig. 1. shows the structure of magnetic gear.
- ✓ Table 1. shows the specifications of the analytical model.
- ✓ coaxial magnetic gear is separated from each other in a non-contact manner by the presence of air gap between Inner rotor and Outer rotor.
- ✓ coaxial magnetic gear has a structure similar to a magnetic coupling, but a steel-pole is located between the inner and the outer.

Analysis of the Pull-out Torque and Torque THD characteristics

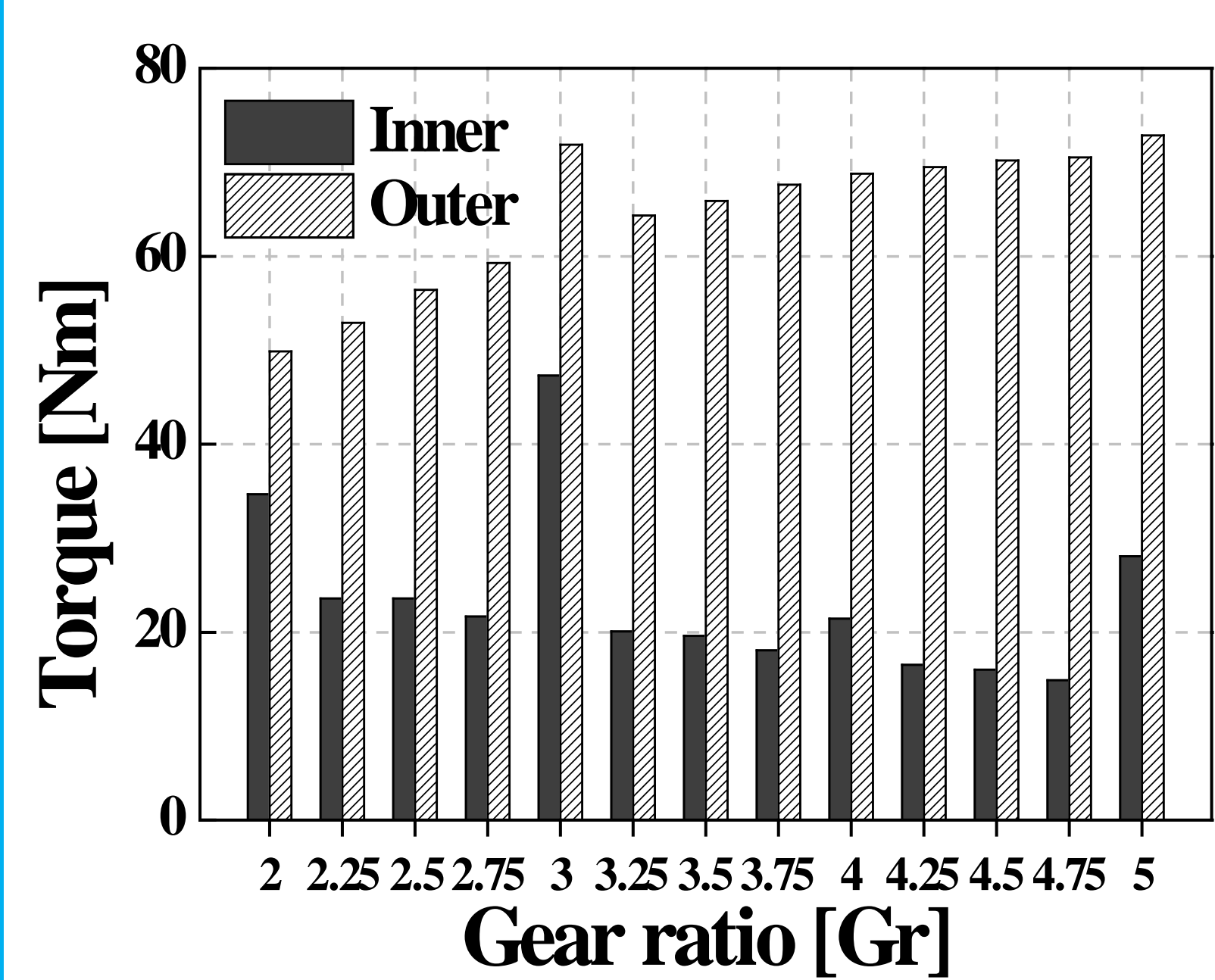


Fig. 2. Analysis of pull-out torque characteristics according to gear ratio

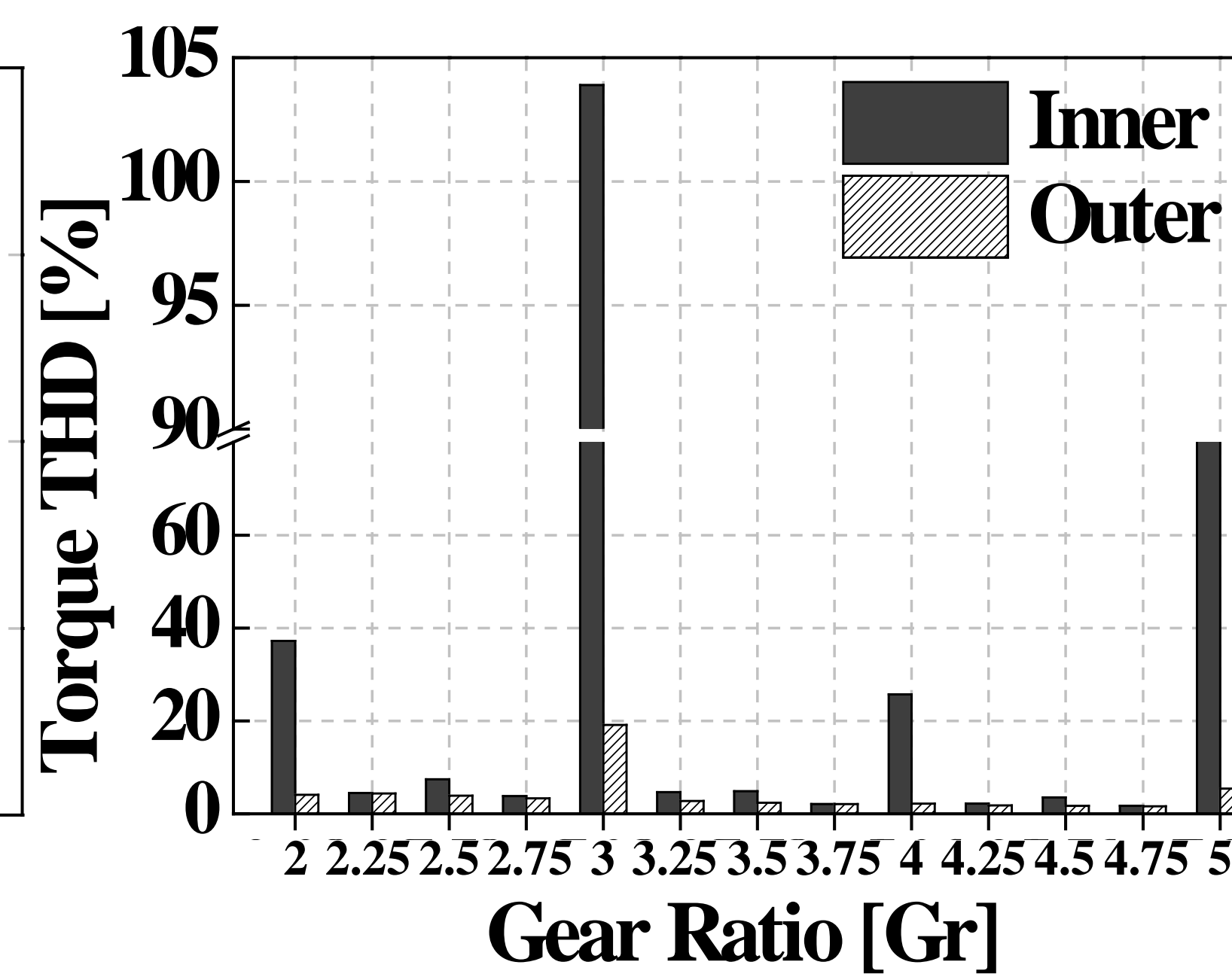


Fig. 3. Analysis of torque THD characteristics according to gear ratio

- ✓ The inner permanent magnet was fixed to 8 poles and then only the number of poles of the outer permanent magnet was changed to analyze the characteristics of the coaxial magnetic gear according to the gear ratio.
- ✓ Fig. 2. shows the pull-out torque characteristics according to the gear ratio.
- ✓ Fig. 3. shows the torque THD according to the gear ratio.
- ✓ Torque THD increases when the gear ratio is an integer.
- ✓ As the gear ratio increases, the outer torque value increases accordingly.
- ✓ The number of steel-poles is denoted as N_s and can be obtained as follows.
- ✓ The gear ratio is given by G_r and can be obtained as follows.
- ✓ The formula for torque THD is as follows.

$$N_s = P_{in} + P_{out}$$

$$G_r = \frac{P_{out}}{P_{in}} \quad \bullet \quad THD = \left(\frac{T_2^2 + T_3^2 + \dots + T_n^2}{T_1} \right) \times 100$$

Analysis of torque and torque ripple characteristics in transient analysis

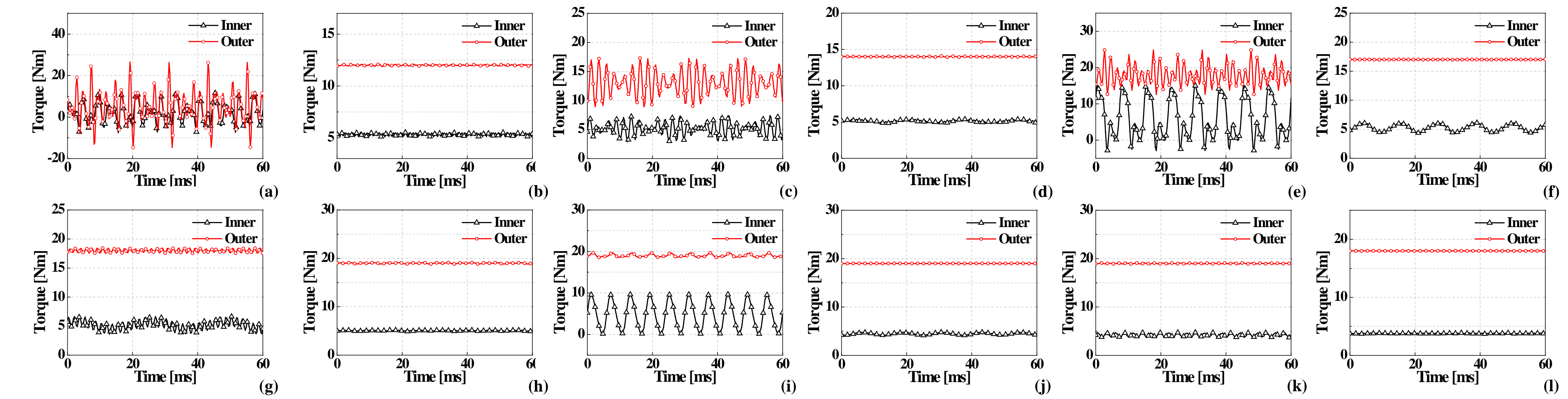


Fig. 4. Torque characteristics according to gear ratio of transient analysis

(a) Gr 2, (b) Gr 2.25, (c) Gr 2.5, (d) Gr 2.75, (e) Gr 3, (f) Gr 3.25, (g) Gr 3.5, (h) Gr 3.75, (i) Gr 4, (j) Gr 4.25, (k) Gr 4.5, (l) Gr 4.75

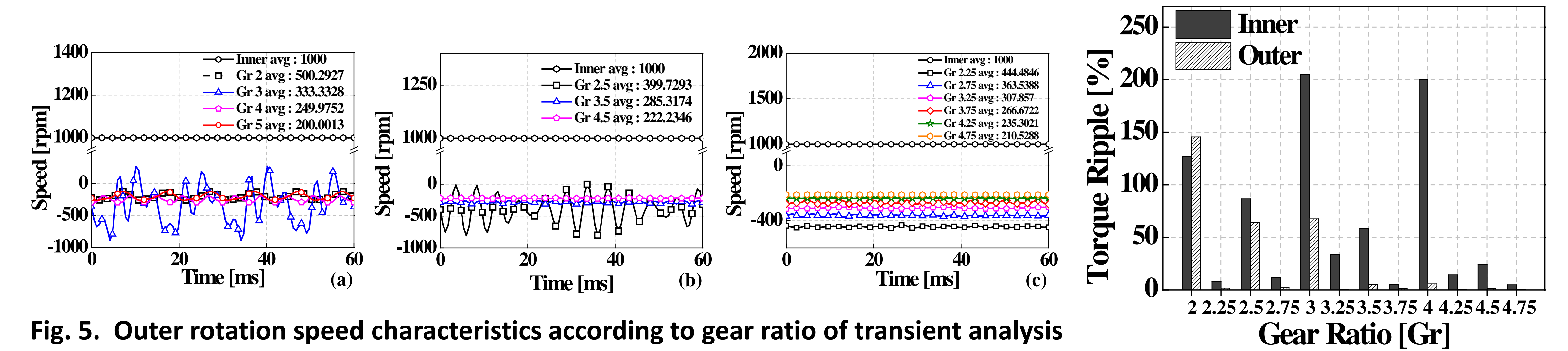


Fig. 5. Outer rotation speed characteristics according to gear ratio of transient analysis
(a) Integer gear ratio, (b) Half gear ratio, (c) Quarter gear ratio

Fig. 6. Torque ripple characteristic according to gear ratio of transient analysis

- ✓ Fig. 4. shows the torque characteristics of the transient analysis according to the gear ratio of the magnetic gear.
- ✓ Fig. 5. shows the rotational speed characteristics of the outer rotor according to the gear ratio.
- ✓ There are many ripple in the torque and outer rotating characteristics at integer gear ratio.
- ✓ Fig. 6. shows torque ripple characteristics of transient analysis according to gear ratio.
- ✓ The torque ripple can be obtained as shown in the following equation.

$$\bullet \quad \text{Torque Ripple} = \frac{T_{max} - T_{min}}{T_{avg}} \times 100$$

Conclusion

- ✓ In the pull-out analysis, the integer gear ratio exhibits a high torque THD. However, torque THD is greatly reduced in half and quarter gear ratios.
- ✓ Torque THD of pull-out analysis in transient analysis has a great effect on torque ripple.
- ✓ Integer gear ratio is rotational speed of the outer rotor is not constant and ripple occurs severely, but Half and quarter gear ratio rarely occur. Among them, quarter is the smallest.
- ✓ The torque ripple of the transient analysis also affects the rotational speed of the outer rotor.
- ✓ It would be efficient to design a coaxial magnetic gear with quarter gear ratio.