The Number of Magnet Poles Decision Method of Magnetic Gear for Torque Ripple Reduction

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Abstract

The power transmission of magnetic gears, based upon the attractive force of magnets, does not involve direct contact between the power transmission shafts. Thus, vibration or noise, due to friction, can be reduced. However, magnets and iron cores, which are the main components of magnetic gears, generate cogging torque. This increases torque ripples that are the cause of the noise and vibration of permanent-magnet (PM) machines. In this study, a torque ripple reduction method, using the combination of number of poles and number of pole pieces was proposed. This method uses the structural characteristics of magnetic gears only. This method was suggested instead of the existing torque ripple reduction methods for PM machines to reduce the torque ripples of magnetic gears. Furthermore, the correlation between the numbers of poles, pole pieces, and torque ripples was analyzed. From this analysis, a design guideline that minimizes torque ripples in the initial design of magnetic gears was proposed.

Key words – Number of pole piece, Number of pole, Magnetic gear, Torque ripple reduction, Gear ratio, LCM, GCD,

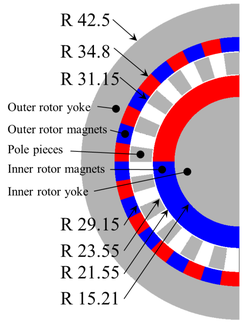
Conclusion

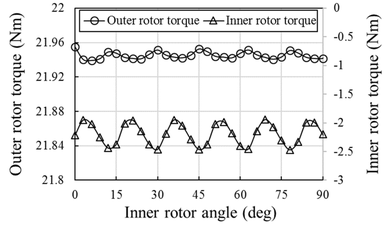
- Fractional gear ratios exhibited the lowest torque ripples.
- For models with high ripples, additional analysis was conducted, and it was further confirmed that the LCM and the GCD between the number of poles and number of pole pieces directly affect ripples.
- The analysis of other arbitrarily extracted models show the same results as the results noted above thus ensuring the reliability of this analysis.

- Therefore, based on the above results, it is proposed that integer gear ratios be avoided as much as possible. Fractional gear ratios should be selected in order to minimize ripples when magnetic gears are designed. If integer gear ratios must be used, it is advised to use the combination with the highest LCM between the number of poles and number of pole pieces as well as the GCD of one must be selected to obtain the lowest ripples.

Models and Principles

Basic model: 4/40 Poles, 22Pole pieces





	Inner rotor	Outer rotor
RPM	4,000	400
Average torque (Nm)	2.2	21.9
Torque ripple (%)	24.5%	0.1%
Gear ratio	10 : 1	

Combinations of Poles and Pole pieces

$$G_r = \frac{P_2}{P_1} = \frac{\omega_1}{\omega_2} \quad (1) \qquad N_s = \frac{P_1 + P_2}{2} \quad (2)$$

G_r:Gear ratio, P_1:Inner rotor poles, P_2:Outer rotor poles, ω_1: Revolution speed of Inner rotor, ω_2: Revolution speed of Outer rotor, N_s: Number of stationary pole piece

	Range
Number of Inner poles	From 4 to 20, Step: 2
Number of Outer poles	From 6 to 40, Step: 2
Gear ratio	From 1.1 : 1 to 10.0 : 1

LCM, GCD Analysis

Inner Poles	Outer Poles	Pole Piece	LCM		GCD		Ratio
			in-pp	out-pp	in-pp	out-pp	
4	40	22	44	440	2	2	10.0
4	38	21	84	798	1	1	9.5
4	36	20	**20**	180	**4**	**4**	**9.0**
4	34	19	76	646	1	1	8.5
4	32	18	36	288	2	2	8.0
4	30	17	68	510	1	1	7.5
4	28	16	**16**	112	**4**	**4**	**7.0**
4	26	15	60	390	1	1	6.5
4	24	14	28	168	2	2	6.0
4	22	13	52	286	1	1	5.5
4	20	12	**12**	60	**4**	**4**	**5.0**
4	18	11	44	198	1	1	4.5
4	16	10	20	80	2	2	4.0
4	14	9	36	126	1	1	3.5
4	12	8	**8**	24	**4**	**4**	**3.0**
4	10	7	28	70	1	1	2.5
4	8	6	12	24	2	2	2.0
4	6	5	20	30	1	1	1.5

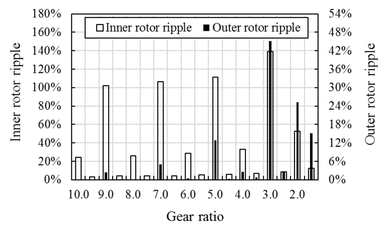
High ripple gear ratio 9:1, 7:1, 5:1, 3:1 have low LCM value and high GCD value

Inner Poles	Outer Poles	Pole Piece	LCM		GCD		Ratio
			in-pp	out-pp	in-pp	out-pp	
20	40	30	60	120	10	10	2.0
18	36	27	54	108	9	9	2.0
16	32	24	48	96	8	8	2.0
14	28	21	42	84	7	7	2.0
12	36	24	24	72	12	12	3.0
10	30	20	20	60	10	10	3.0
8	40	24	24	120	8	8	5.0
8	24	16	16	48	8	8	3.0
6	30	18	18	90	6	6	5.0
6	18	12	12	36	6	6	3.0

It is advised to use the combination with the highest LCM between the number of poles and number of pole pieces as well as the GCD of one must be selected **to obtain the lowest ripples.**

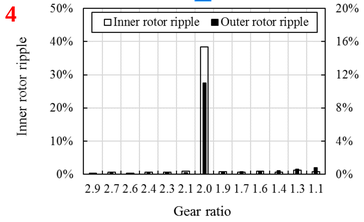
Torque Ripple Results

Torque Ripple according to The Combination of Poles and Pole Pieces



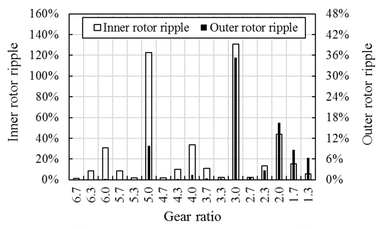
Inner Poles: **4**

High ripple gear ratio 9:1, 7:1, 5:1, 3:1



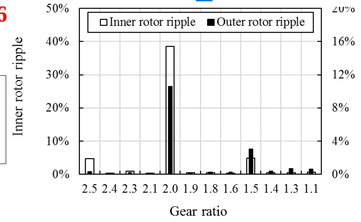
Inner Poles: **14**

High ripple gear ratio 2:1



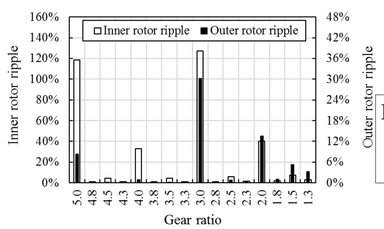
Inner Poles: **6**

High ripple gear ratio 5:1, 3:1



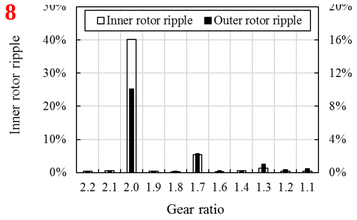
Inner Poles: **16**

High ripple gear ratio 2:1



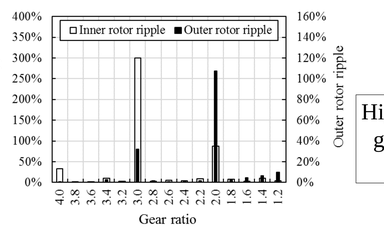
Inner Poles: **8**

High ripple gear ratio 5:1, 3:1



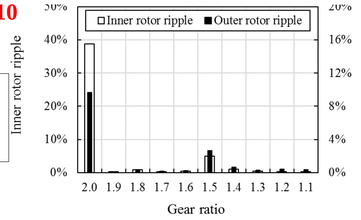
Inner Poles: **18**

High ripple gear ratio 2:1



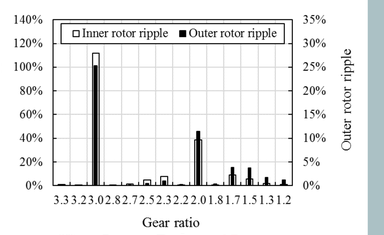
Inner Poles: **10**

High ripple gear ratio 3:1, 2:1



Inner Poles: **20**

High ripple gear ratio 2:1



Inner Poles: **12**

High ripple gear ratio 3:1

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