A Novel Magnetic Gear with Unequal Halbach Array and Spoke Permanent Magnets

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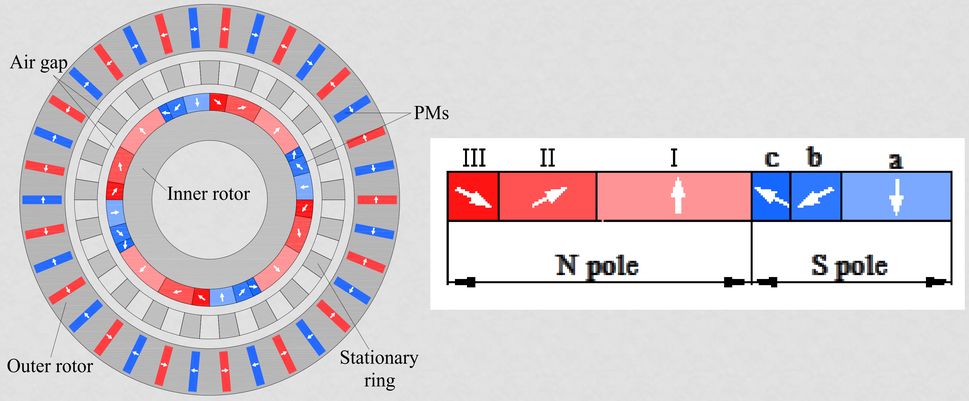
1. Introduction

Compared with mechanical gear, magnetic gear has the advantages of low acoustic noise, low vibrations, reduced maintenance and inherent overload protection. Although magnetic gears have many merits, the early magnetic gears are radial parallel shaft structures; this kind of structural magnetic gear has the problems of single transmission mode, low transmission ratio, low torque density and low utilization rate of PMs. In this paper, a magnetic gear with unequal Halbach arrays and spoke structure is proposed to improve the output torque of MG. The inner rotor has an asymmetric N-S pole structure, the permanent magnets (PMs) on the inner rotor of the MG are arranged in Halbach arrays with unequal magnetic poles, and PMs on the outer rotor are Spoke-type.

2. Basic Theory and Topology of Magnetic Gear



(a) (b)

Fig. 1. MG topology: (a)Proposed model, (b)PMs on the inner rotor.

The expression of the number of spatial harmonics generated in the inner and outer air gaps is as follows:

$$P_{ikm} = kN_s + mP_i$$

According to the Maxwell Stress tensor, the electromagnetic torque of the inner and outer rotor can be expressed as follows:

$$T_{m\_i} = \frac{L_{ef} R_i^2}{u_0} \int_0^{2\pi} B_{r\_i} B_{\theta\_i} d\theta$$

3. Application Example

TABLE I PARAMETERS OF PROPOSED MG

QUANTITY	Value
Outer radius of the inner rotor yoke	40mm
Thickness of PMs on the inner rotor	5mm
Thickness of stationary ring	8mm
Inner radius of the outer rotor yoke	55mm
Outer radius of the outer rotor yoke	70mm
Height of PMs on the outer rotor	14mm
Width of PMs on the outer rotor	3.8mm
Axial length	80mm
Remanence of PMs	1.1T
Pole-pairs inner rotor	4
Pole-pairs outer rotor	17
Numbers of PM segments	3
S/N ratio	0.95

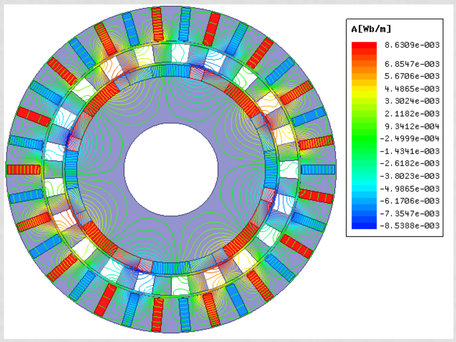


Fig. 2. Magnetic flux line

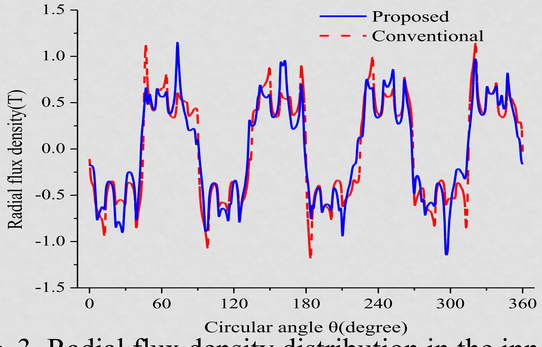


Fig. 3. Radial flux density distribution in the inner air gap

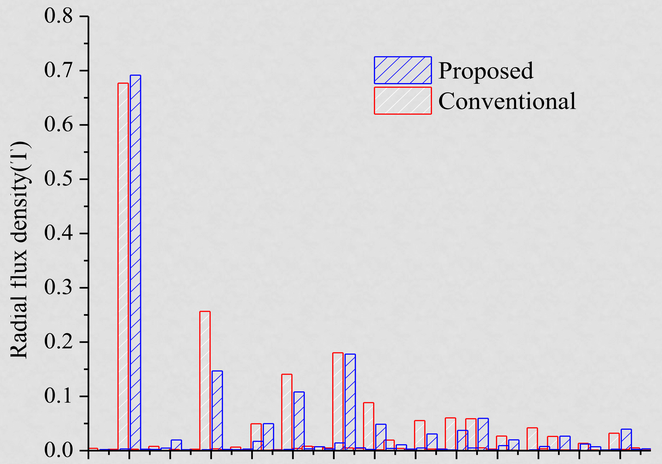


Fig. 4. Radial harmonic spectra in the inner air gap

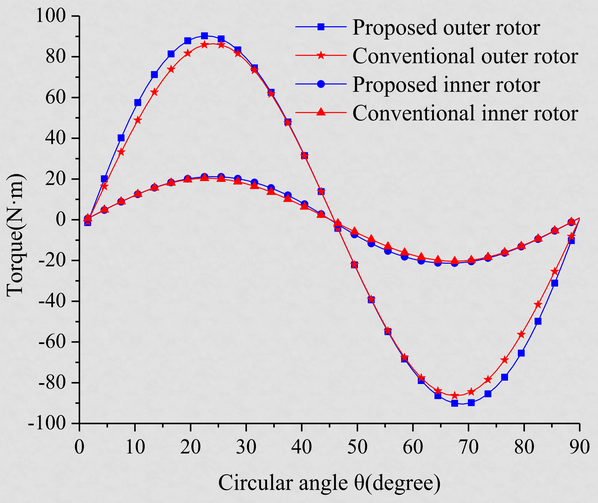


Fig. 5. Torque-angle curves

4. Conclusion

A Novel MG with unequal Halbach arrays and spoke structure has been proposed and analyzed. Asymmetric poles and unequal Halbach arrays can improve the fundamental wave of air gap magnetic field and reduce high-order non-working harmonics. It can be seen that the torque of proposed CMG is 4.62% higher than the conventional CMG.