

I. Introduction

- The improvement of power/torque density in electric machines is a main issue on electric vehicle (EV) and hybrid EV (HEV) applications.
- Axial flux permanent magnet machines have attracted a lot of attention, which enhance the merits of simple and compact structure, short axial length, and large power/torque density.
- A novel 3-phase 24-stator-slot/10-rotor-pole(24s/10p) rotor permanent magnet axial switched-flux (RPM-ASF) machine is proposed and analysis, which enhances the torque output capability and improves power/torque density of the machine.

II. Topology and Operating Principle

- Compact structure** **Simple stator**
- Short axial length** **High efficiency**
- High power/torque density**
- Large torque output capability**
- Strong overload capacity**
- Brushless AC operation**

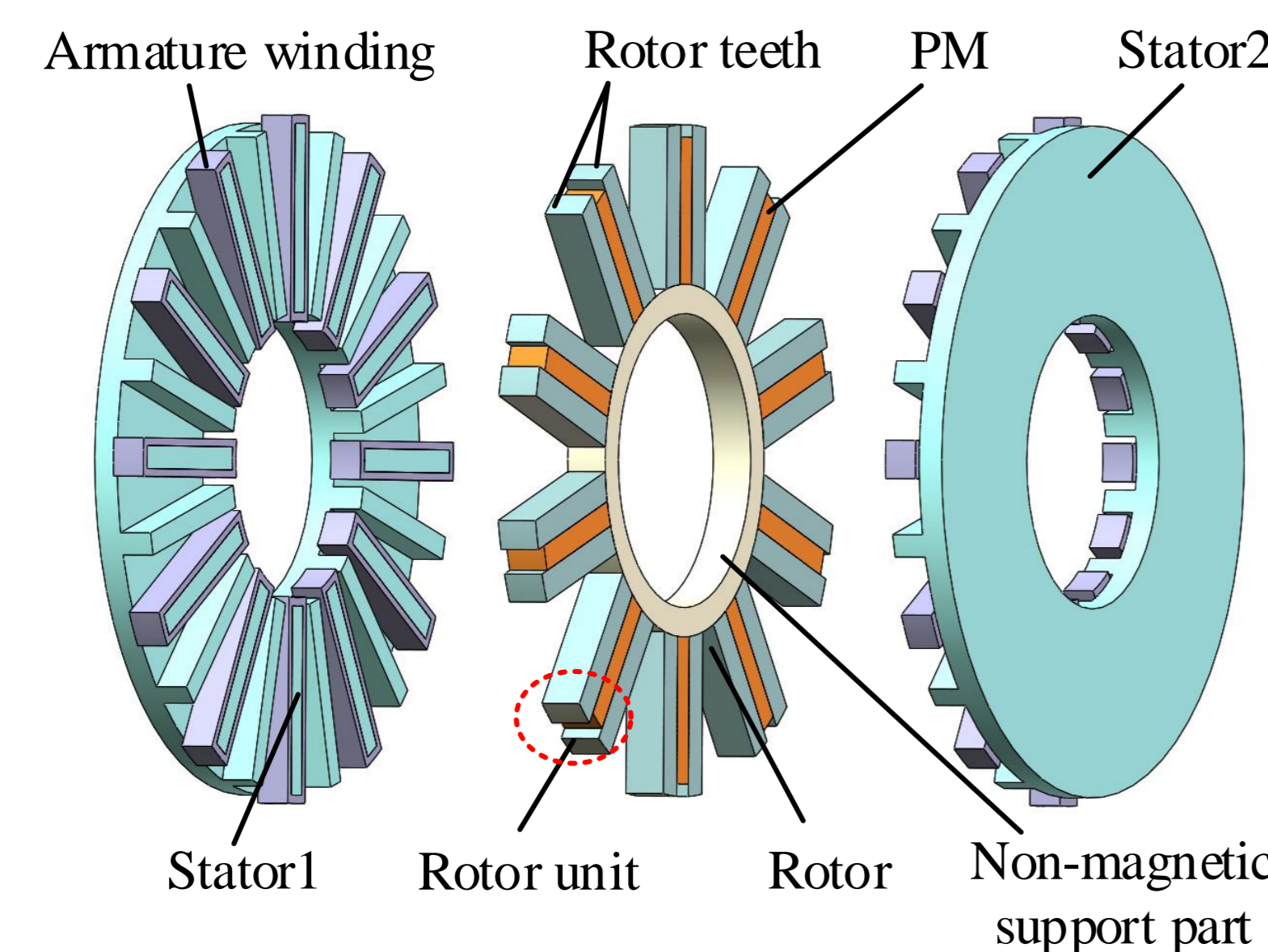


Fig. 1. 3-D topology of 24s/10p RPM-ASF machine.

TABLE I.
Major Design Parameters.

Items	Value
Stator slot number, P_s	24
rotor pole number, P_r	10
rotor pole-pair number, P_{PPN}	10
rated output power, P_N (W)	600
rated speed, n_n (r/min)	750
rated armature current, I_N (A)	3.5
outer diameter of stator, D_{so} (mm)	250
inner diameter of stator, D_{si} (mm)	140
stator length, l_s (mm)	25
stator yoke length, l_{sy} (mm)	8
rotor length, l_r (mm)	14
stator tooth arc, β_{st} ($^\circ$)	10
stator slot arc, β_{ss} ($^\circ$)	5
PM arc, β_{pm} ($^\circ$)	8
PM length, L_{pm} (mm)	50
PM volume, V_{pm} (mm ³)	6790
rotor tooth arc, β_r ($^\circ$)	9
air gap length, g (mm)	1
armature winding turns, N_a	336

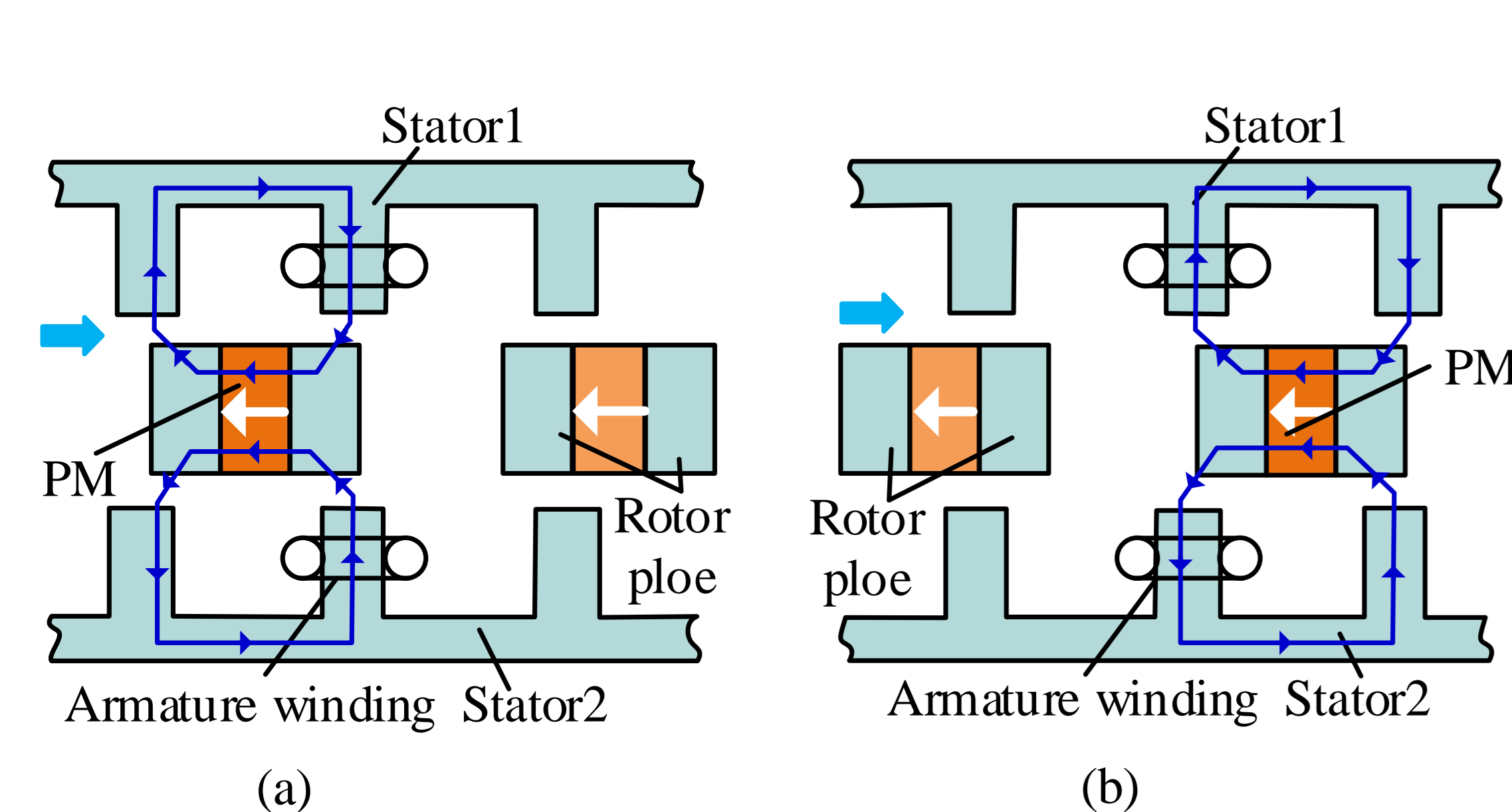


Fig. 2. Operating principle with different rotor position based on 2-D plane. (a) Position 1. (b) Position 2.

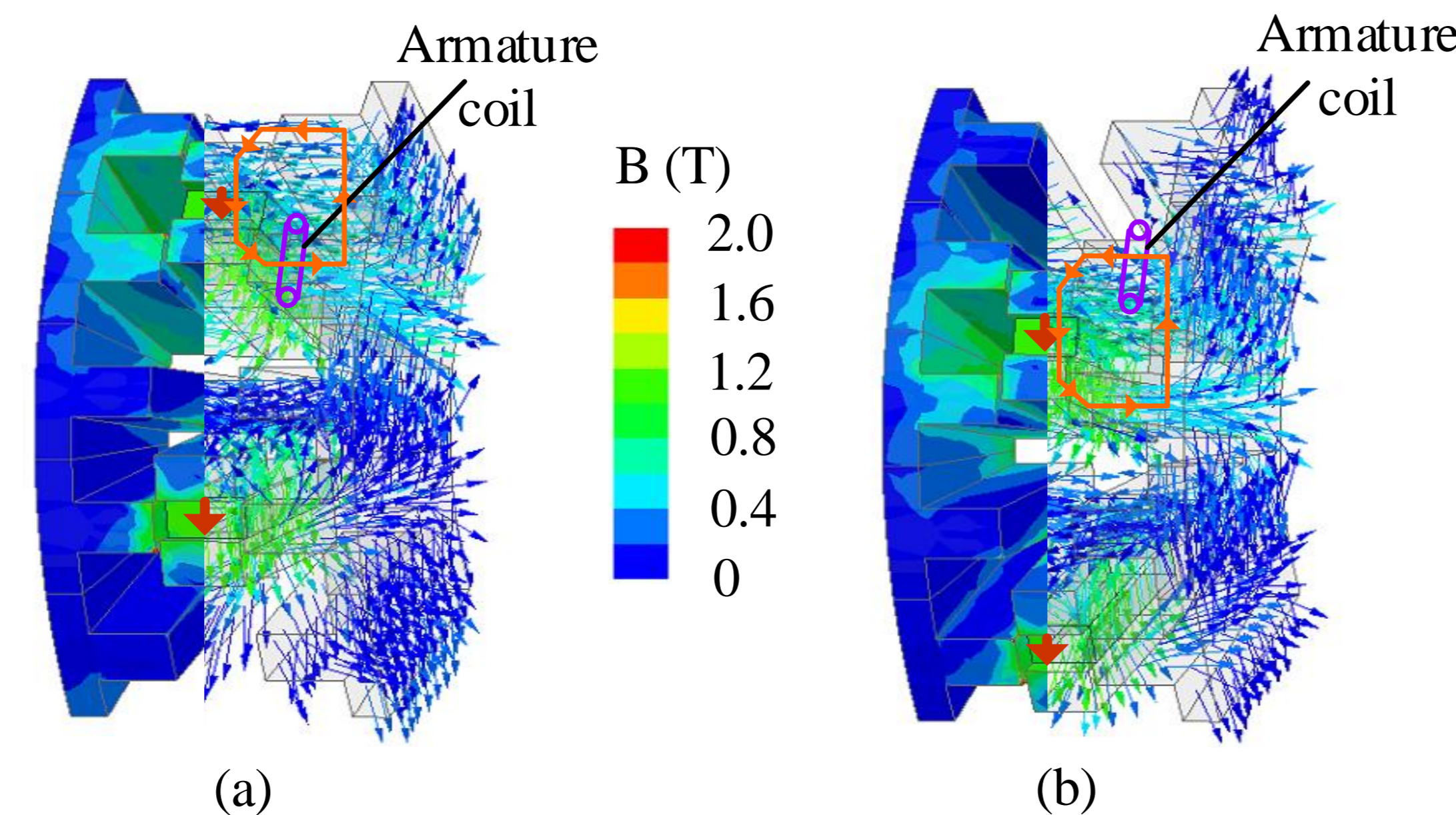


Fig. 3. Open-circuit magnetic field distribution. (a) Position 1 ($\theta_m = 0^\circ$). (b) Position 2 ($\theta_m = 18^\circ$).

III. Electromagnetic Performance Analysis

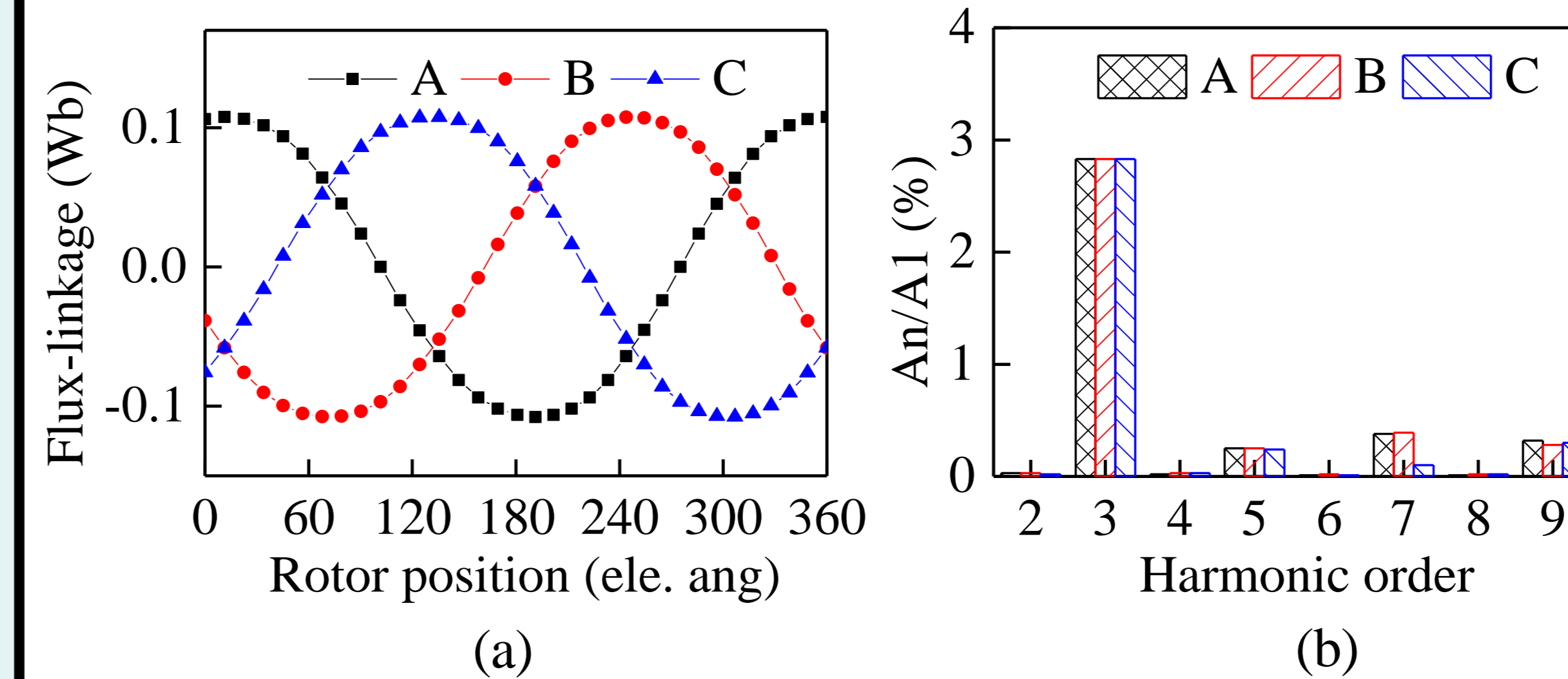


Fig. 4. Open-circuit 3-phase flux-linkage waveforms. (a) Waveforms. (b) Spectra.

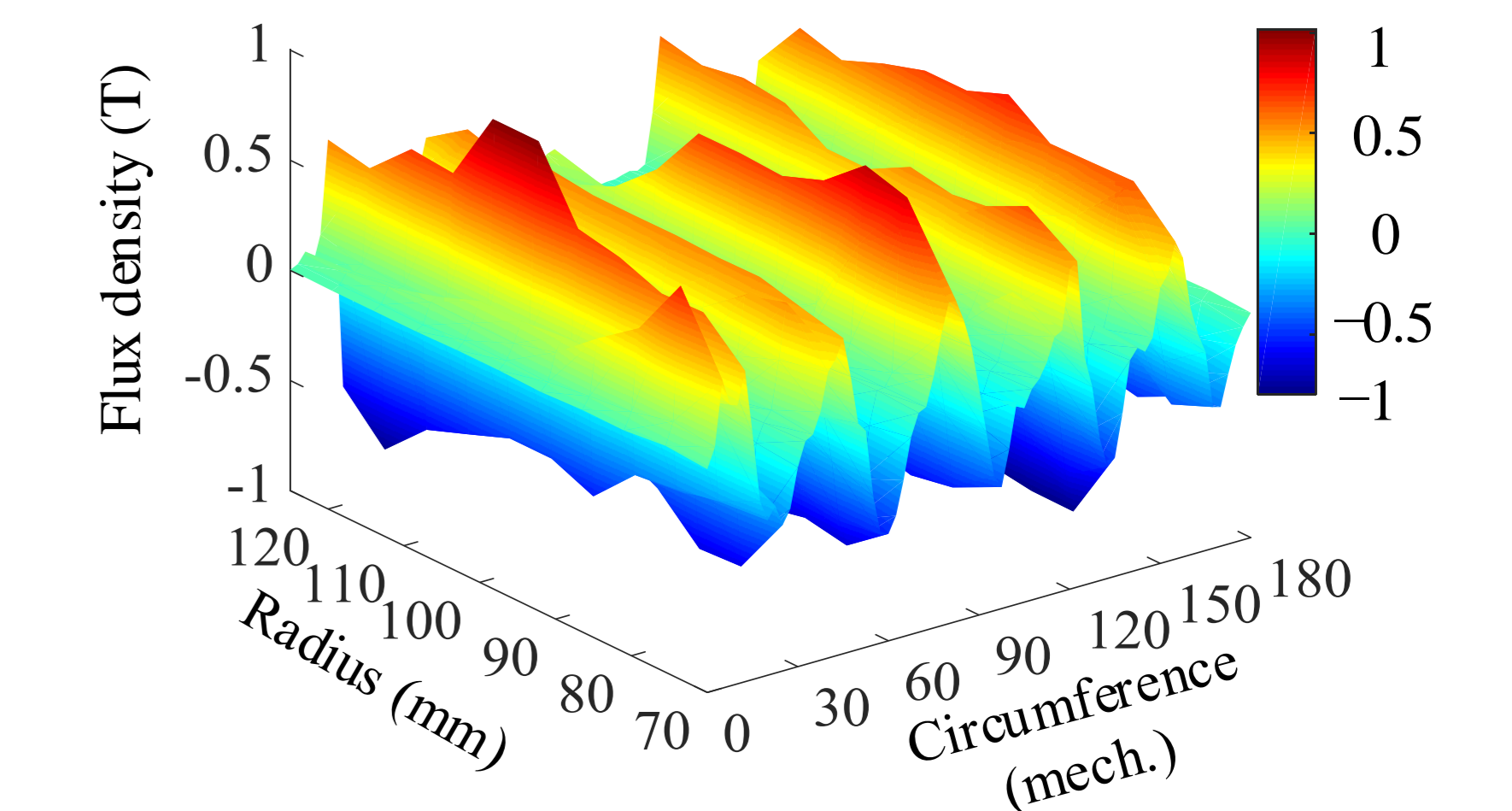


Fig. 5. 3-D air-gap flux density.

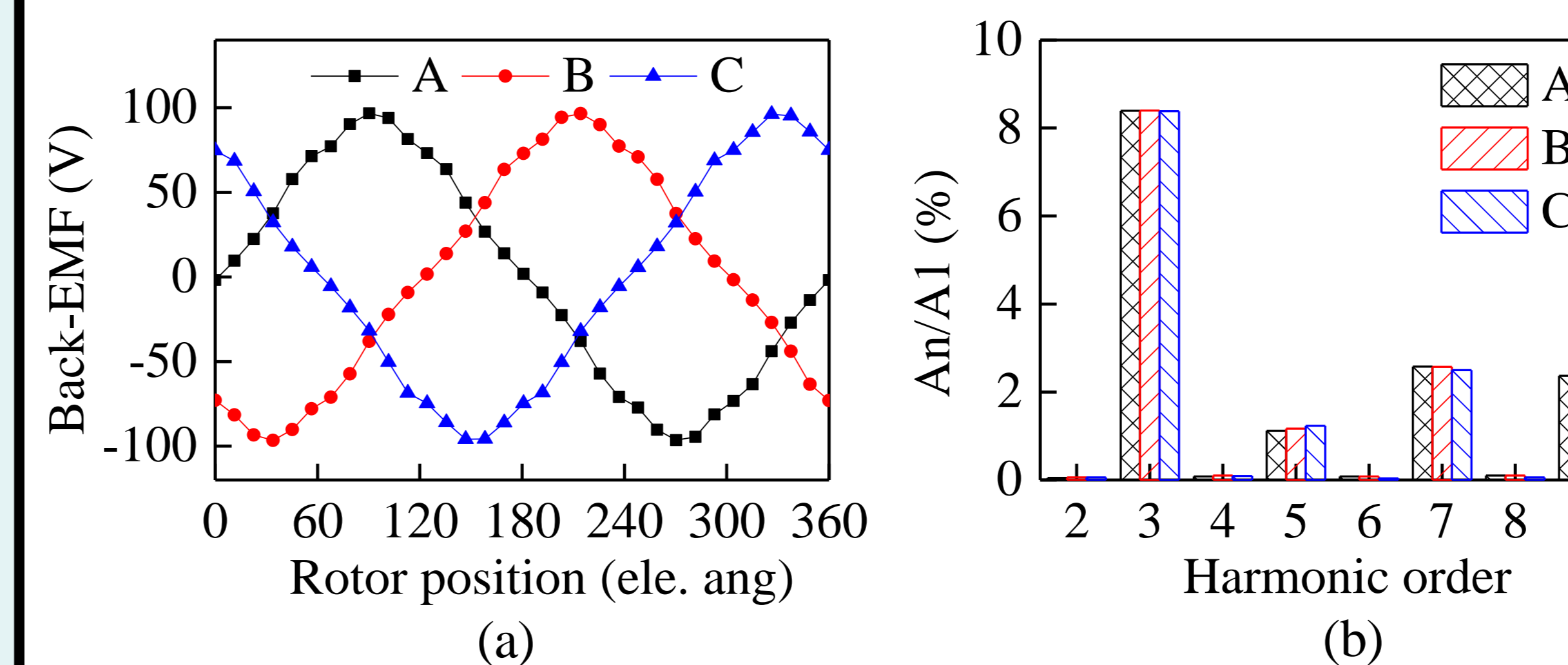


Fig. 6. Open-circuit 3-phase back-EMF waveforms. (a) Waveforms. (b) Spectra.

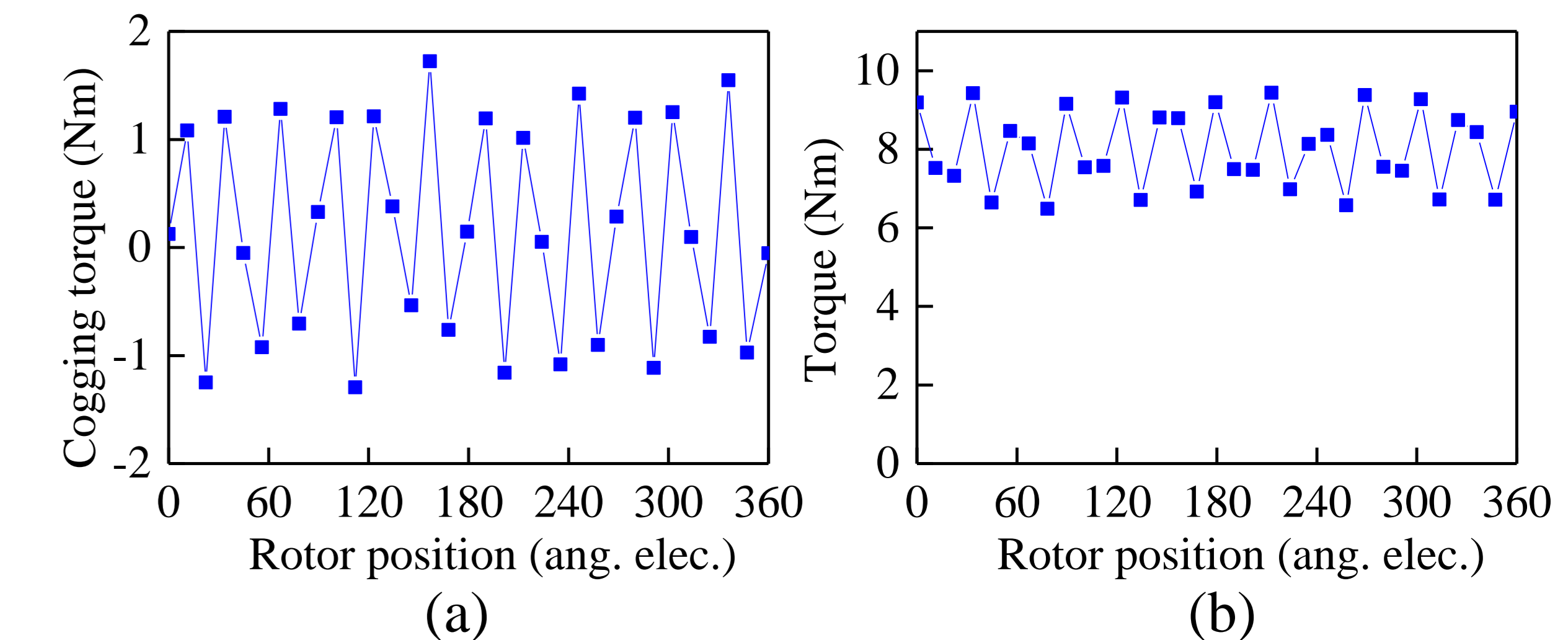


Fig. 7. Torque characteristics. (a) Cogging torque. (b) Electromagnetic torque.

IV. Conclusion

- ◆ A novel RPM-ASF machine with the structure of dual-stator rotor permanent magnet is proposed and analyzed. The configuration and operating principle are analyzed.
- ◆ The electromagnetic performance of the RPM-ASF machine is investigated by 3-D finite element method. The analysis results demonstrate that the machine has symmetric and sinusoidal flux-linkage as well as back-EMF, and enhances large torque output capability.
- ◆ The large characteristic and high power/torque density of the proposed machine is validated. It is very attractive for EV/HEV applications.