Ferrite PM Optimization of SPM BLDC Motor for Oil-Pump Applications According to Magnetization Direction

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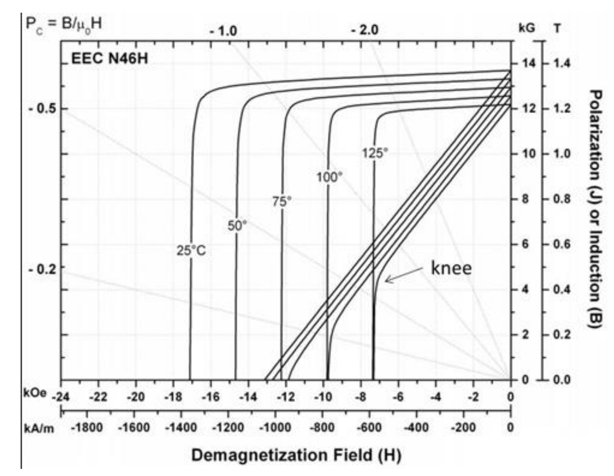
MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019

Background

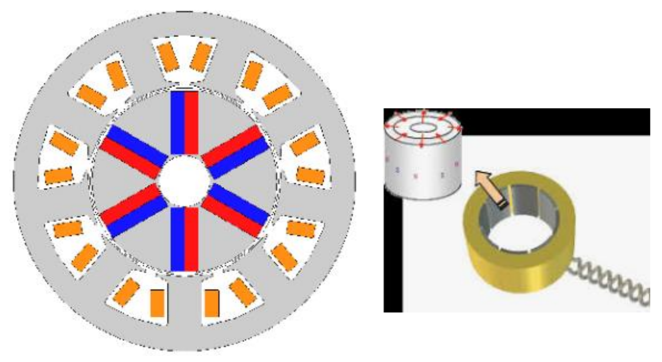
This paper proposes the optimization of an isotropic ferrite magnet shape and magnetization direction to enable maximize back-EMF and torque density of SPM BLDC. Four different oil pump motor models of general magnet shape and magnetization direction are selected, and then FEM analysis is carried out with four different magnetization directions for each of four models. In order to replace Nd-PMs by Fe-PMs, performance improvement of motor is needed according to the optimization of the magnet shape and the magnetization direction. The magnetization direction of the ferrite magnet can be parallel, polar, or radial, depending on the manufacturing process. In previous studies, SPM BLDC often used radial magnetization direction magnets to obtain rectangular back EMF to reduce the torque ripple, However we found that this method is only applicable to Nd-PM, but in the case of Fe-PMs, the SPM-BLDC must use the parallel magnetization direction to ensure the torque density.

1. Introduction

[1]



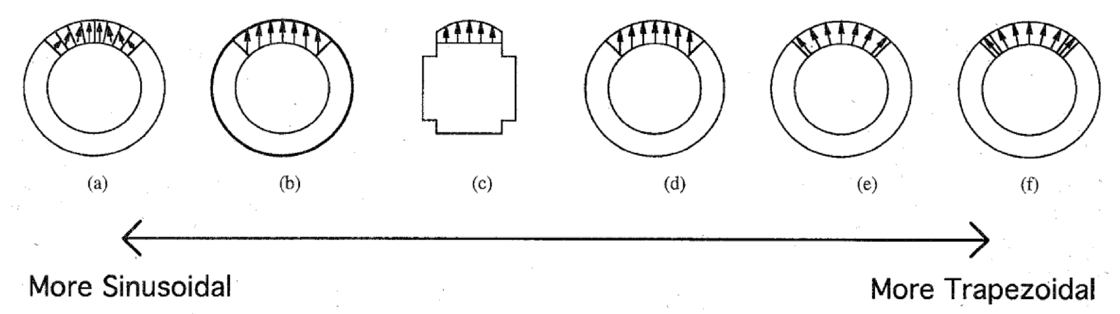
high-temperature demagnetization



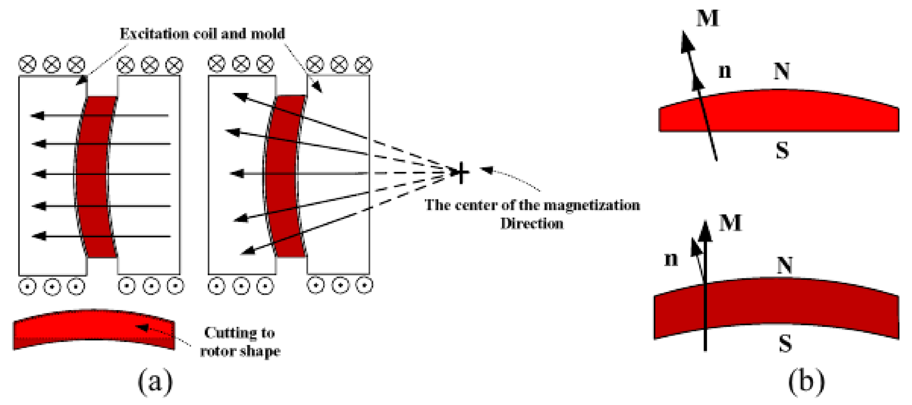
Impulse Magnetizer

2. Concept of FE-PM SPM-BLDC

A. Magnet Shapes and Magnetization Directions

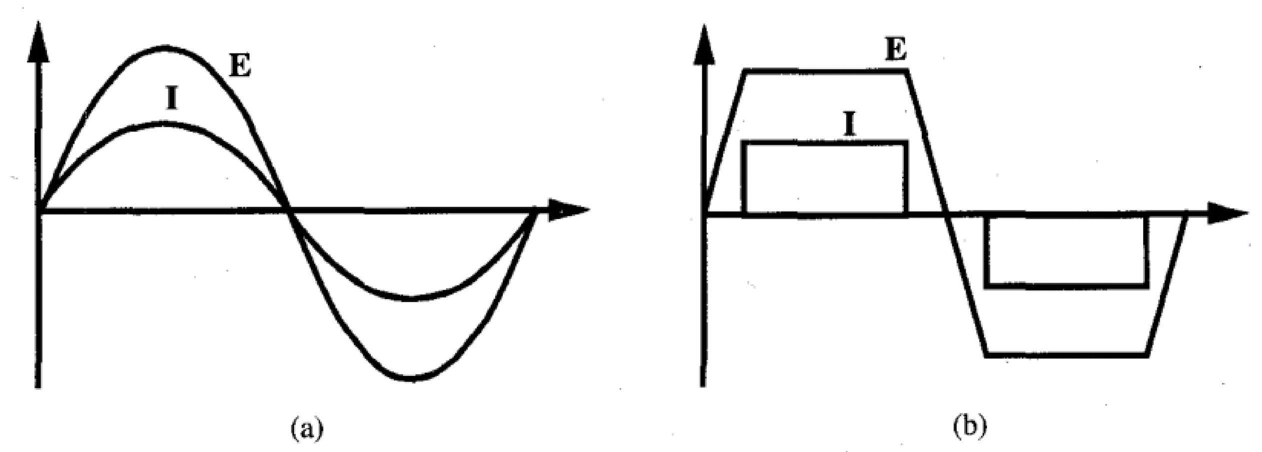


airgap flux distributions illustrated with four-pole motors. (a) Blocked. (b) Magnetic can. (c) Tapered. (d) Parallel. (e) Radial. (f) Interleaved. [2]



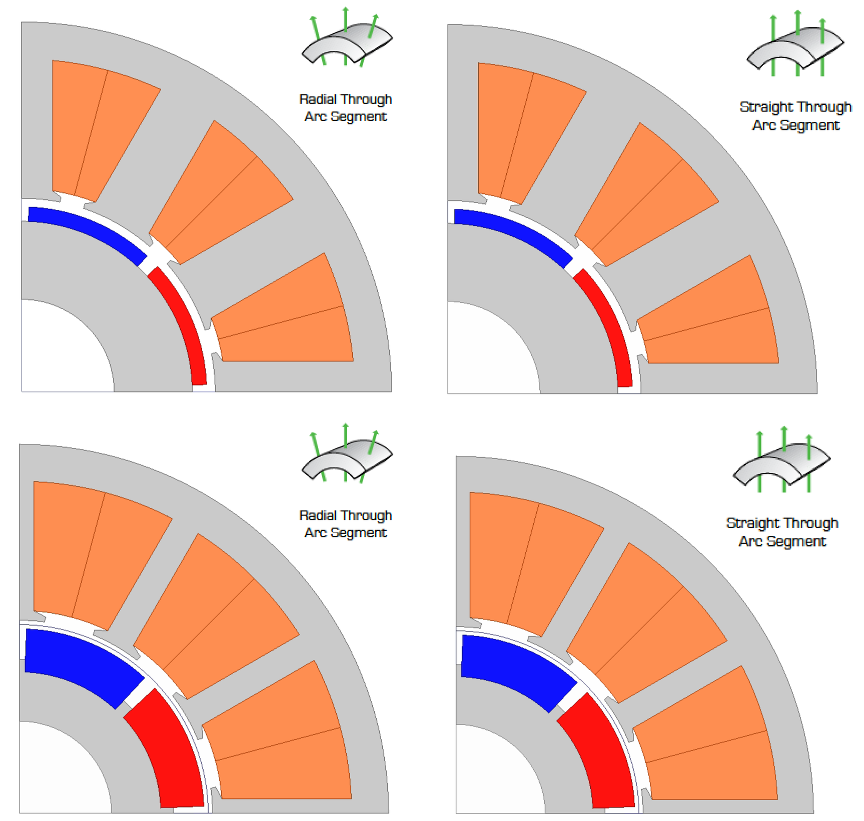
The manufacturing process of PM.

B. Compare the Back-EMF Waveform of PM Shape



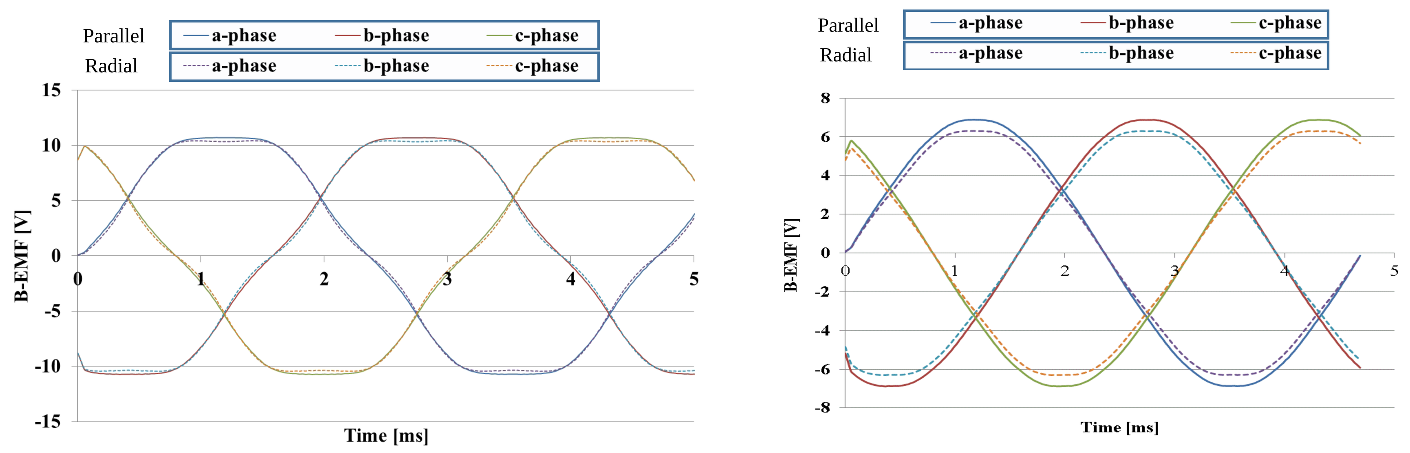
Idealized phase excitation wave forms for the two major class of PMAC machines (a) BLAC (b) BLDC

3. Machine comparison



Item	Unit	Model 1	Model 2	Model 3	Model 4
Steel lamination	-	50PN470 (S18)			
PM Grade	-	NdFe35		NMF-12	
Number of poles /slots	mm	60			
Rotor outer Dia.	mm	60			
Stack length	mm	40			
Air-gap length	mm	0.7			
PM size (length/ width)	mm	1.2		4.5	
Turns per slot	-	74	74	104	104
Slots area	mm^2	67	67	94.4	94.4

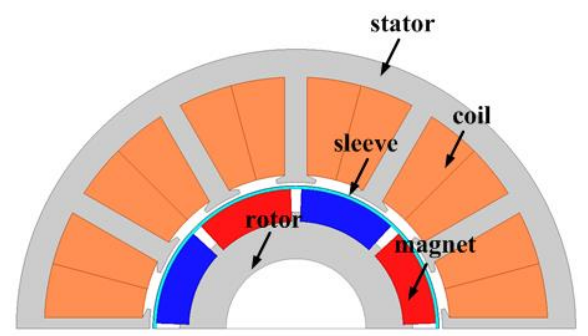
A. No-load operation comparison



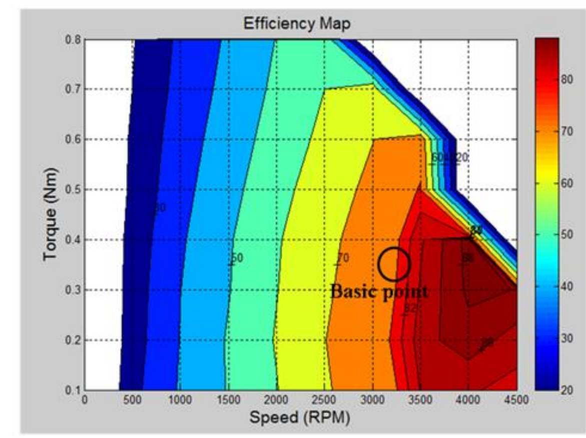
B. load operation comparison

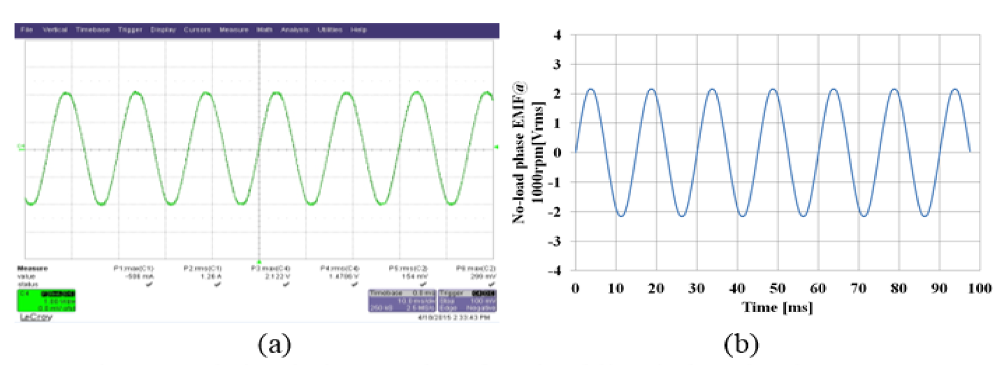
		Phase-Resistant	Vdc	RPM	Phase current Arms	Current density A/mm^2	Torque [Nm]	pk2pk	Torque ripple [%]	Pout	Copper loss	Core loss	%
Radial model	120	0.0672	8.5	3200	10.88	6.16	0.354	0.055	15.53	118.6	23.87	4	81.0
	150	0.0672	8.1	3200	11.85	6.71	0.351	0.114	32.47	117.6	28.32	5.9	77.5
Parallel model	120	0.0672	8.5	3200	9.09	5.14	0.321	0.047	14.64	107.6	16.66	3.9	84.0
	150	0.0672	8.6	3200	11.4	6.45	0.378	0.101	26.71	126.7	26.21	6.3	79.6

4. Experiment



final Parameter design model





Experiment and simulation results of no-load line-induced voltage at 1000 r/min. (a) Experiment. (b) Simulation.

MAIN DIMENSIONS AND DESIGN SPECIFICATIONS

Items	FEM	EXPERIMENT	ERROR
Base Speed	3200rpm	3194rpm	0.18%
Torque	0.348Nm	0.359Nm	3.0%
Power	116.55	120.3W	3.5%
Efficiency	84.2%	82.9%	1.3%

[1] https://www.nidec.com/enNA/technology/story/eop/
[2] Pulsating Torque Minimization Techniques for Permanent Magnet AC Motor Drives-A Review, Thomas M. Jahns, and Wen L. Soong , IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 43, NO. 2, APRIL 1996

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