論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	VIBRATION AND ACOUSTIC NOISE REDUCTION OF SWITCHED RELUCTANCE MOTOR BY ANALYTICAL CURRENT DERIVATION AND RADIAL FORCE SHAPING
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12855号, 授与年月日:2024年9月20日, 学位の種別:課程博士, 審査員:千葉 明,藤田 英明,赤塚 洋,萩原 誠,清田 恭平,小坂 卓
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12855号, Conferred date:2024/9/20, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Doctor of Philosophy (2024)

(Electrical and Electronic Engineering)

Tokyo Institute of Technology

Tokyo, Japan

TITLE: Vibration and Acoustic Noise Reduction of Switched Reluctance Motor by Analytical Current Derivation and Radial Force Shaping

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Outline

The switched reluctance motor (SRM) presents an appealing option in electric-vehicle propulsion systems due to its cost-effectiveness and lack of rare-earth materials. However, its inherent vibration and acoustic noise pose significant challenges, limiting its widespread adoption in such applications.

The primary source of vibration and acoustic noise in SRMs is the electromagnetic radial forces acting on the stator. In SRMs with numerous stator poles, flattening the radial-force sum emerges as a viable strategy to mitigate the dominant breathing mode vibration. Flattening the radial-force sum is the elimination of the multiples of the third temporal radial-force component. Traditionally, achieving this flattening has relied on either analytical current derivation or numerical sweeping of current parameters.

This thesis introduces a novel analytical approach that considers phase shifts in the current waveform to achieve radial-force sum flattening. This comprehensive mathematical derivation significantly reduces torque ripple and rms current compared to previous methods in the literature. However, magnetic saturation considerations were absent from this initial analytical derivation.

Acknowledging this limitation, a second method is proposed: radial-force shaping based on the logistic function. By integrating offline lookup tables of radial-force characteristics, this method ensures a constant sum of radial forces even under magnetic saturation conditions.

Nevertheless, the radial-force shaping method exhibits significant current peaks, necessitating higher-rated inverters and escalating costs. To address this challenge, a third hybrid approach is presented, combining analytical current derivation with radial-force estimation and shaping. This synergistic method not only mitigates current peaks compared to standalone radial-force shaping but also maintains the desired radial-force sum flattening.

Finite element analysis and experimental verification underscore the efficacy of the proposed methods. Comparative analyses against conventional techniques and previous literature demonstrate superior performance in minimizing vibration and acoustic noise, torque ripple, rms current, and peak current. Specifically, the investigation focuses on an 18/12 SRM constructed from high-silicon steel, reaffirming the versatility and applicability of the findings across SRM designs.