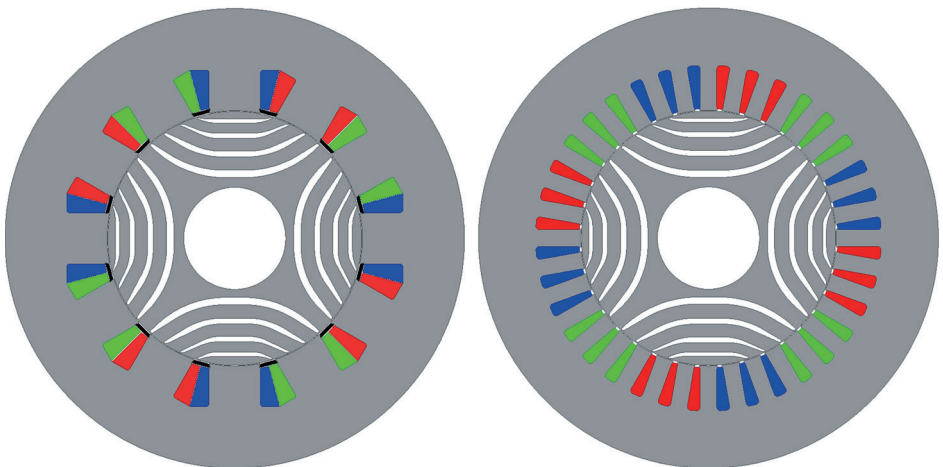


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Elektrische Antriebstechnik und Aktorik

Hrsg.: Prof. Dr.-Ing. Dieter Gerling

Bastian Lehner

**Design Aspects for Concentrated Winding
Synchronous Reluctance Machines for
Automotive Traction Applications**



Design Aspects for Concentrated Winding Synchronous Reluctance Machines for Automotive Traction Applications

Bastian Martin Lehner

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Abstract

Synchronous reluctance machines are an attractive choice for automotive traction drives. Due to the absence of permanent magnet material, induction cage or field excitation windings in the rotor, they benefit from low rotor losses, low manufacturing costs and no potential resource problems related to rare earth materials. A reasonable application of concentrated stator windings to synchronous reluctance machines could offer even additional advantages, such as increased torque density and efficiency, simplified machine construction and increased robustness. Therefore, the main objective of this research is the examination of design aspects and the feasibility of concentrated winding synchronous reluctance machines for the application as automotive traction drive.

The result of this study is a summary of the main principle of torque production in synchronous reluctance machines, the analytical description of the linear and saturated dq -model, the effect of iron loss and leakage inductance and a comprehensive analysis of the power factor behavior of synchronous reluctance machines. Furthermore, the torque-speed characteristics of synchronous reluctance machines and the particular challenge associated with the application of concentrated stator windings are examined.

Based on the findings and the requirements set for automotive traction application, two machines are examined in a design-based comparison. The examined machines, one equipped with a double layer concentrated winding and one with a full pitch distributed winding, are built and evaluated at a machine test bench. The machine evaluation at the test bench largely confirms the validity of the simulation models and underlines the individual differences of the concentrated and distributed winding machine. Moreover, a new method for adapting the rotor design of synchronous reluctance machines to sustain the high rotational speeds required for an automotive traction drive is discussed.

In addition, a new approach for torque ripple minimization, based on a direct parameter variation of an asymmetric rotor flux barrier design, is presented.

Kurzfassung

Synchronreluktanzmaschinen sind eine mögliche Alternative für Traktionsantriebe im Automobilbereich. Aufgrund des Fehlens von Permanentmagnetmaterial, Kurzschlusskäfig oder Felderregerwicklungen im Rotor profitieren sie von geringen Rotorverlusten und niedrigen Herstellungskosten und unterliegen nicht der potenziellen Ressourcenproblematik von Seltenerdmaterialien. Eine sinnvolle Applikation konzentrierter Statorwicklungen in Synchronreluktanzmaschinen könnte darüber hinaus weitere Vorteile bieten, wie z.B. erhöhte Drehmomentdichte und Effizienz, einen vereinfachten Aufbau der Maschine sowie eine erhöhte Ausfallsicherheit. Daher ist das Hauptziel dieser Arbeit die Untersuchung von Entwurfskriterien und der Eignung von Synchronreluktanzmaschinen mit konzentrierten Wicklungen für den Einsatz als Fahrzeugantrieb im Automobilbereich.

Das Ergebnis dieser Arbeit ist eine Zusammenfassung der grundlegenden Theorie zur Drehmomentbildung in Synchronreluktanzmaschinen, der mathematischen Beschreibung eines linearen und eines gesättigten dq -Modells, der Auswirkungen von Eisenverlusten und der Streuinduktivität und einer umfassenden Betrachtung hinsichtlich des Leistungsfaktorverhaltens von Synchronreluktanzmaschinen. Darüber hinaus werden die Drehzahl-Drehmoment-Charakteristik von Synchronreluktanzmaschinen und die besondere Herausforderung hinsichtlich der Anwendung von konzentrierten Statorwicklungen untersucht.

Basierend auf den Erkenntnissen und den Anforderungen an die Traktionsanwendung im Automobil werden zwei Maschinen, eine mit einer zweischichtigen konzentrierten Wicklung und eine mit einer ungesehnten verteilten Wicklung, in einem entwurfsbasierten Vergleich untersucht, aufgebaut und auf einem Maschinenprüfstand vermessen. Die Vermessung der Maschinen bestätigt weitgehend die Aussagekraft der Simulationsmodelle und unterstreicht die individuellen Unterschiede der Maschinen mit konzentrierter und verteilter Statorwicklung. Darüber hinaus wird eine neue Methode beschrieben, um den Rotoraufbau von Synchronreluktanzmaschinen an die hohen Drehzahlanforderungen im Automobilbereich anzupassen.

Des Weiteren wird ein neuer Ansatz zur Minimierung von Drehmomentpulsationen vorgestellt, der auf einer direkten Parametervariation eines asymmetrischen Rotordesigns beruht.

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