Lifetime Assessment and Robustness Validation for Automotive Electrical Traction Machines

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Abstract

In the course of this work, lifetime prediction, testing and robustness validation specifically for electrical traction machines are covered. The concept of physical modeling – a combination of analytical multi-physics machine behavior models and lifetime models for machine components which allows lifetime prediction for a specific load and application – is investigated. For several machine components (bearings, magnets, winding, insulation, resin, lamination), lifetime models including physical interactions are set up and parametrized with accelerated lifetime tests.

In the first part basic lifetime and robustness assessment concepts are presented and common temperature-based lifetime models are discussed. A qualitative approach to failure analysis based on chains of effects and classification of possible machine failures is given and useful machine life in terms of key machine parameters is defined.

In the second part lifetime models for bearings, NdFeB magnets, wire insulation, resin and lamination are given. All relevant failure causes, amongst others temperature, temperature cycling, moisture, vibration, mechanical and impact load, voltage and chemical deterioration are investigated, failure mechanisms are discussed and their modes and effects are described. The electromagnetic and thermal machine behavior is modeled analytically and interactions and mutual reactions - also caused by aging - are included (for example relations between coil and magnet temperature, magnet aging and thermal derating). Results for an exemplary machine, application, load and environment are discussed.

The third part covers lifetime tests and model parametrization. An optimization method for temperature cycling tests is given which allows reducing the test duration. Methods for optimizing entire test procedures for lifetime testing and robustness validation are discussed in terms of time and cost savings. Temperature and temperature cycling tests are performed on various types of magnets, lamination (glued and welded), winding (distributed and concentrated), insulation and resin (various resins, casting and impregnation processes). The test results are used to parametrize lifetime models given in the second part.

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