Efficiency Improvement of a High-Speed Permanent Magnet Excited Synchronous Machine by the use of Spot-Welding as Lamination Packaging Technology

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Abstract. In this paper, an efficiency improvement of a high-speed permanent magnet excited synchronous machine (PMSM) by the use of spot-welding as lamination packaging technology is undertaken. Welding, interlocking, clinching and the use of adhesives are typical methods to connect iron stacks of electrical machines. However, these processes deteriorate the magnetic properties of the electrical sheets, thereby decreasing the overall efficiency of the machine. Variations of the spot-welding (symmetrical and unsymmetrical spot-welding) and line-welding (four-, six- and eight-line welds) procedure is performed and analyzed. A semi-physical iron-loss separation method is used to extract the IEM iron loss separation model. These parameters are to be utilized during the finite element simulation to calculate the effective efficiency of the machine while using each joining procedure. A low speed and a high-speed driving cycle will be used to analyze the effects of each procedure on the machine efficiency at the different operating conditions.

For the set-up of a mechanically stable magnetic core of an electrical ac machine, the electrical steel laminations must be firmly connected. Welding, interlocking, clinching and the use of adhesives represent the current state of the art of the mechanical connection of such thin steel sheets. Each of the connecting processes lead directly to the deterioration of the material's magnetic properties. Increased iron losses as well as a decreasing permeability of the electrical steel can be observed. The connection of the single lamination sheets by welding is a commonly used technology. In this process, the sheets are joined mechanically along a seam accompanied by an apparent dissipation of heat along the welding area. This local concentration of dissipated heat yields a thermal degradation and increase of the residual stress distribution inside the material. The residual stress reduces the magnetizability of the electrical steel used due to the Villari-effect. An increase of the eddy-current loss because of the emergence of short-circuits along the welded points can be observed.

In this paper, a method for improving the overall efficiency of a high-speed permanent magnet synchronous machine is discussed. The decreasing effects of the aforementioned weld process (spot-welding) on the eddy-current loss component of iron-loss can be utilized for a high-speed operation, where most of the operations are at higher frequencies. A finite element method simulation of the high-speed permanent magnet synchronous machine is to be conducted and the analysis of the joining process with driving cycles is to be made.

In order to examine the aforementioned effects on the magnetic properties of the material, we utilize the material grade 230-30AP. Ring core shaped magnetic circuits of 60 mm outer diameter, 48 mm inner diameter and a height of about 10 mm are constructed for the purpose of measurements and characterizations of the electromagnetic properties of the magnetic circuit.

Variations of the spot-welding (symmetrical and unsymmetrical spot-welding) and line-welding (four-, six- and eight-line welds) procedure is performed and analyzed. With these procedural variations, different ring cores are constructed and measured. The dependency of

the material degradation on these different procedures are to be quantified and characterized. The utilized welding-laser has a focus length of 300 mm and a fiber diameter of 200 µm.

In particular the technology of an unsymmetrical spot-welding procedure is studied. This is due to its apparently less electromagnetic degradation at higher frequencies compared to other welding procedures. Employing the symmetrical or unsymmetrical spot-welding joins two or three single ring-shaped sheets together in a symmetrical or an unsymmetrical spot-welding pattern. This method reduces in general the number of global eddy-current paths inside the ring core, thereby reducing the generation of eddy-current losses.

With line-seam welding the upper and lower rings are connected in such a way, that a magnetic short-circuiting the ring cores is observed. A semi-physical iron-loss separation method is to be used to extract the IEM iron loss separation model. These parameters are to be utilized during the finite element simulation to calculate the effective efficiency of the machine while using each joining procedure. A low speed and a high-speed driving cycle will be used to analyze the effects of each procedure on the machine efficiency at the different operating conditions.

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