Effect of grain size and magnetic texture on iron-loss components in NO electrical steel at different frequencies

Nora Leuning, Simon Steentjes, Kay Hameyer

Institute of Electrical Machines (IEM), RWTH Aachen University, Germany

Non-oriented electrical steels are used to direct and concentrate the magnetic flux in rotating electrical machines. Due to extending requirements on the power density and efficiency of these machines, higher speeds and a resulting increase of operating frequencies is necessary. Subsequently, the frequency dependence of the magnetic properties of electrical steel sheets becomes more and more important. Magnetic loss of ferromagnetic materials depends on several factors. For FeSi electrical steels the primary factors are the chemical composition, the geometry, i.e., the sheet thickness, the microstructure and texture, and the mechanical residual stress within the laminations. These contributing factors relate to different loss mechanisms which exhibit different frequency dependence. Therefore, basic material design relations for low frequencies cannot be directly transferred to high frequencies. Hence, the classification of materials based on their magnetic loss at a nominal point of 1.5 T and 50 Hz together with the sheet thickness, is not sufficient. The microstructure, texture and geometry can give indication of the relative frequency dependence of materials with similar chemical compositions.

In this study, a loss separation according to (1) is performed on samples that were produced on an experimental production route that comprises hot rolling, cold rolling and annealing. The processing parameters were deliberately selected to create different microstructures, textures and final thicknesses from the same alloy.

$$P_{\text{total}} = P_{\text{hyst}} + P_{\text{cl}} + P_{\text{exc}} \qquad (1)$$

The loss components are determined from quasi-static magnetic measurements and measurements up to 1000 Hz, on a single-sheet-tester. In Figure 1 the three loss components are displayed for two frequencies. They highlight the change of beneficial microstructures for high frequencies and inductions compared with low frequency requirements. The detailed evaluation of the microstructure and texture across the entire sheet thickness enables further correlation to the different losses. The quantification of the texture by means of the so-called *A*-parameter, enables the consideration of magnetic anisotropy and directional dependence of the magnetic loss.

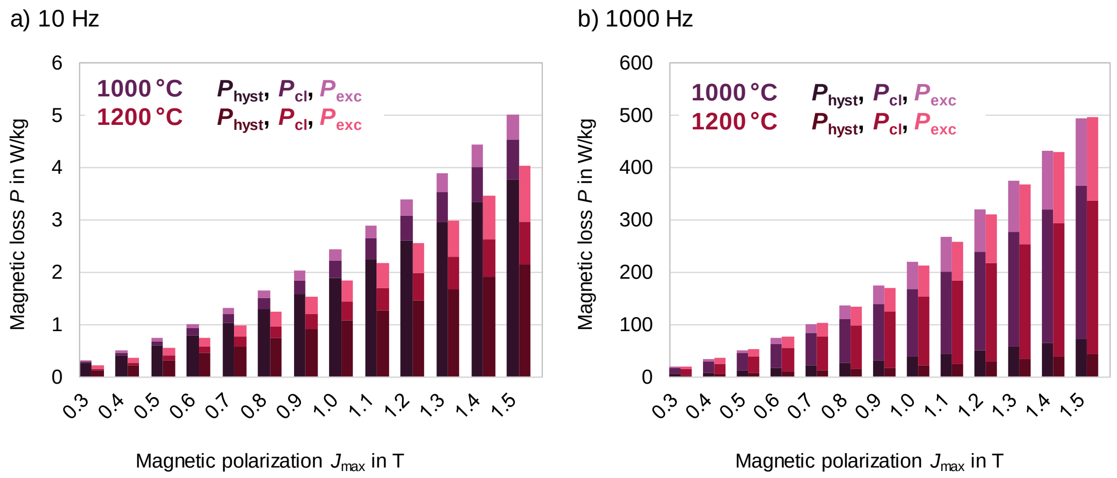

Figure 1. Magnetic loss components of a 0.5 mm, 2.4 wt.% FeSi after two different final annealing temperatures, a) at 10 Hz, b) at 1000 Hz.