Optimizing crystallographic texture for enhanced magnetic properties in non-oriented electrical steels

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This study investigates the design of crystallographic texture in 3.2 wt.% silicon non-oriented electrical steel to enhance magnetic properties. By exploring the relationship between processing conditions and texture formation, we aim to develop strategies for optimizing magnetic performance, thereby improving the efficiency of electric motors.

Keywords: Non-oriented electrical steel; Crystallographic texture; Magnetization anisotropy; EBSD

1. Introduction

The magnetic performance of non-oriented electrical steel is strongly governed by its microstructure and crystallographic texture. To support the design of steels with enhanced magnetic properties, this work investigates the evolution of texture during key processing steps (cold rolling, final annealing, and shear cutting) using a combination of experiments and simulations. The results are correlated with magnetizability and iron losses.

2. Results and discussion

Microstructure and texture evolution during processing is studied using ultra-high-resolution Electron Backscatter Diffraction (EBSD). In NO steels, the development of specific textures such as ⟨100⟩/ND (θ-fiber) and cube texture ({001}⟨100⟩) contributes to improved magnetic properties by promoting easy magnetization in the sheet plane [1]. However, conventional processing often fails to establish sufficient amounts of these components.

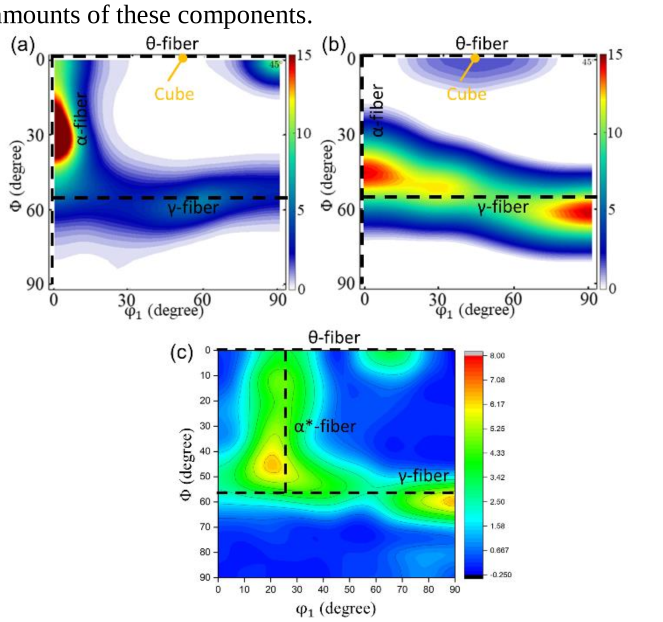

Figure 1: Crystallographic texture (φ2=45° section of the ODF) of (a) conventionally cold-rolled state, (b) optimized cold-rolled condition [2], and (c) final annealed state.

After hot rolling, cold rolling is used to refine the microstructure and induce favorable deformation textures. As shown in Figure 1a, the conventional cold-rolled texture does not include desirable cube deformation texture. However, according to our recent findings [2], careful tailoring of cold rolling conditions can significantly enhance beneficial texture components, see Figure 1b, thereby improving magnetizability and reducing iron losses.

Subsequently, final annealing enables recrystallization, which governs the final microstructure and magnetic response. The recrystallized texture, see Figure 1c, is sensitive to temperature and holding time, requiring precise control to meet performance targets. Through extensive annealing experiments conducted under a variety of controlled conditions, we derive optimal parameters that result in a favorable balance of grain size and texture, leading to enhanced magnetic properties.

After final annealing, steel sheets are typically shear-cut to create laminations for electric machine cores. However, shear-cutting introduces residual stresses that deteriorate the magnetic properties (iron losses and magnetizability). Minimizing this requires careful selection of shear-cutting parameters, such as cutting speed, clearance, and tool sharpness. This work examines the residual stresses induced by punching with different shear-cutting parameters. Data from a single sheet tester is used to correlate these parameters with magnetic properties.

References

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