Cold Rolling Process Simulation: Analyzing Mechanical and Microstructural Development in Electrical Steels

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Abstract

Electrical steels are the primary soft ferromagnetic materials used in the electrical industry, especially for applications such as magnetic cores made of thin laminates in transformers. Their magnetic properties are closely tied to a specific crystallographic texture characterized by centimetre-sized grains aligned along the Goss orientation. This texture is the result of recrystallization mechanisms and abnormal grain growth during the final annealing stage, also affected by the texture from prior cold deformation (1).

Despite the importance of this process, the factors within the deformed state which control recrystallization and abnormal grain growth mechanisms remain not fully understood due to its complexity and heterogeneity (2). To bridge this knowledge gap, this work models the cold rolling stage to better characterize the mechanical and microstructural evolution of electrical steels. The aim is to improve our understanding of the intricate interplay between cold deformation and the resulting material properties in Fe-Si steels. A methodology has been developed to better simulate the deformation experienced at both the surface and core of the material. Using a macroscopic finite element modelling of the rolling process, the velocity gradient tensor associated with the deformation was extracted and used as input data for a self-consistent polycrystalline simulation, using a newly integrated dislocation-based hardening model (3). Mechanical tests, including tensile and shear loading at various angles relative to the rolling direction, were performed on both initial and deformed states to validate the model. Additionally, texture evolution was monitored both experimentally and through simulations, offering a comprehensive view of the material's response throughout the deformation process.

The study focuses on the early passes of industrial cold rolling to assess the impact of industrial parameters such as rolling speed, roll geometry, or temperature, and to capture the texture-dependent microstructural and mechanical properties.

Key words: VPSC, Finite elements, Texture, Dislocations, Mechanical Behavior

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