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Tracking Texture Components in Grain-Oriented Electrical Steel: Evolution of their Mechanical and Microtructural Properties during Cold Rolling

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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 in transformers, which are made of thin laminates. Their magnetic properties are closely linked to a specific crystallographic texture characterised by centimeter-sized grains aligned along the Goss orientation. This texture results from recrystallization mechanisms and abnormal grain growth during the final annealing stage, which is also affected by the texture resulting from prior cold deformation. Despite its importance, the factors controlling recrystallization and abnormal grain growth mechanisms in the deformed state remain poorly understood due to the complexity and heterogeneity of the process. In an attempt to bridge this knowledge gap, this study models the cold rolling stage in order to characterise the mechanical and microstructural evolution of electrical steels more effectively. The aim is to improve our understanding of the intricate interplay between cold deformation and the resulting properties of Fe-Si alloys. A methodology has been developed to better simulate deformation at both surface and core of the material. Macroscopic finite element modelling of the rolling process was used to extract the velocity gradient tensor associated with the deformation, which was then used as input data for a self-consistent polycrystalline simulation (VPSC) integrating a dislocation-based hardening

law. The work hardening and recovery parameters were determined using experimental mechanical test results. Careful consideration must be given to these parameters, as they impact the distribution of activated systems and dislocations between different slip families and texture components. Different simulations are performed depending on whether the centre, surface or full thickness of the sheet is modelled. The properties extracted for each orientation are examined during deformation and compared between simulation types. Goss grains do not appear to behave drastically differently to grains in other orientations, particularly since the percentage of Goss grains after the first pass remains very low (around 1%). As expected, the γ-fibre stored more dislocations than the α-fibre. Nevertheless, this approach provides new opportunities to study the differences between texture components, offering a better understanding of subsequent recrystallization and abnormal Goss grain growth during closed-vessel annealing.

Keywords:

Grain-Oriented Fe-Si Cold Rolling Visco-Plastic Self-Consistent Simulation Texture