Refining the Identification Methodology for Describing Heterogeneous Fe-Si Materials Using the Viscoplastic Self-Consistent Approach

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Abstract

Electrical steels stand as the predominant soft ferromagnetic materials in the electrical industry. Their applications are mainly magnetic cores in the form of slender laminates within transformers. The magnetic properties of these steels are directly linked to a very specific crystallographic texture composed of centimetre-sized grains aligned along the Goss component. This texture is known to be directly linked with recrystallizations mechanisms and abnormal grain growth during the final annealing process and influenced by the cold deformation texture.

Because of the complexity and heterogeneity of the deformed state, the identification of the elements within this state controlling the mechanisms of recrystallization and then abnormal growth are not yet been achieved. Thus, for a better understanding of the link between deformation and subsequent recrystallization mechanisms, the rolling stage is modelled in the present work. As a first step, a viscoplastic self-consistent approach is selected, in order to have access to both textures and hardening evolutions. The overarching objective is to provide a qualitative and quantitative prediction of the microstructure and mechanical behaviour resulting from cold deformation induced by the rolling process. It is thus fundamental to establish an accurate representation of the heterogeneous Fe-Si material, before this step.

To this end, a novel identification methodology is introduced in this work. The mechanical tests conducted to identify and validate the model involve tensile loading at varying angles with respect to the rolling direction. The material behaviour is captured through a dislocation-based hardening model integrated in the viscoplastic self-consistent polycrystal framework. Then, the information required for the determination of the material constitutive law, such as grain morphology, fragmentation modes, and heterogeneous microstructure, is discussed for enhance alignment with experimental data. This identification methodology aims to advance our understanding of the intricate interplay between cold deformation and the resultant material properties in Fe-Si steels.

Keywords: VPSC, Cold rolling, Texture, Microstructure, Dislocations, Mechanical behaviour

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