On the Correlation between Microstructure, Texture and Magnetic Induction in Non-oriented Electrical Steels

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Introduction

It is well known that the microstructure: grain size, precipitations, internal local stresses and the intensities of the magnetically relevant texture components as well as the magnitude of magnetostriction determine the magnetization behaviour in soft magnetic materials. There is still no quantitative model, which describes these relations in the complete range of magnetic inductions. There are only a limited amount of papers, which establish a correlation between the measured texture intensities and the values of B25, i.e. the magnetic induction B at a field of 2500A/m. In this paper, the existing different models for the dependence of B as a function of the value of the applied field on the relevant structural parameters and on the intrinsic material parameters will be critically evaluated. A more general model is proposed.

Experimental

The materials chosen for this work were commercially produced non-oriented electrical steels with a Si content up to 3.3 wt% Si. The grain size D was determined by optical microscopy using the linear intercept method. The crystallographic texture was measured using Electron BackScatter Diffraction (EBSD). The magnetic measurements were done for Epstein strips using a commercial Brockhaus® magnetic measurement unit. For discussing the effects of the crystallographic texture of the material the so-called A parameter obtained from the EBSD data was calculated. The value of A gives the "quality of the magnetic texture", characterized by defining the angle between one of the <100> directions of easy magnetization of the crystals in the polycrystalline material and the direction of the macroscopic magnetization vector M in the material. The externally applied magnetic field, which is represented by this magnetization vector M, makes an angle with the RD of the sheet. A is the texture parameter in the case that the magnetic field vector M is applied in a direction making an angle with the rolling direction.

Results & Discussion

A and Magnetic Anisotropy Energy

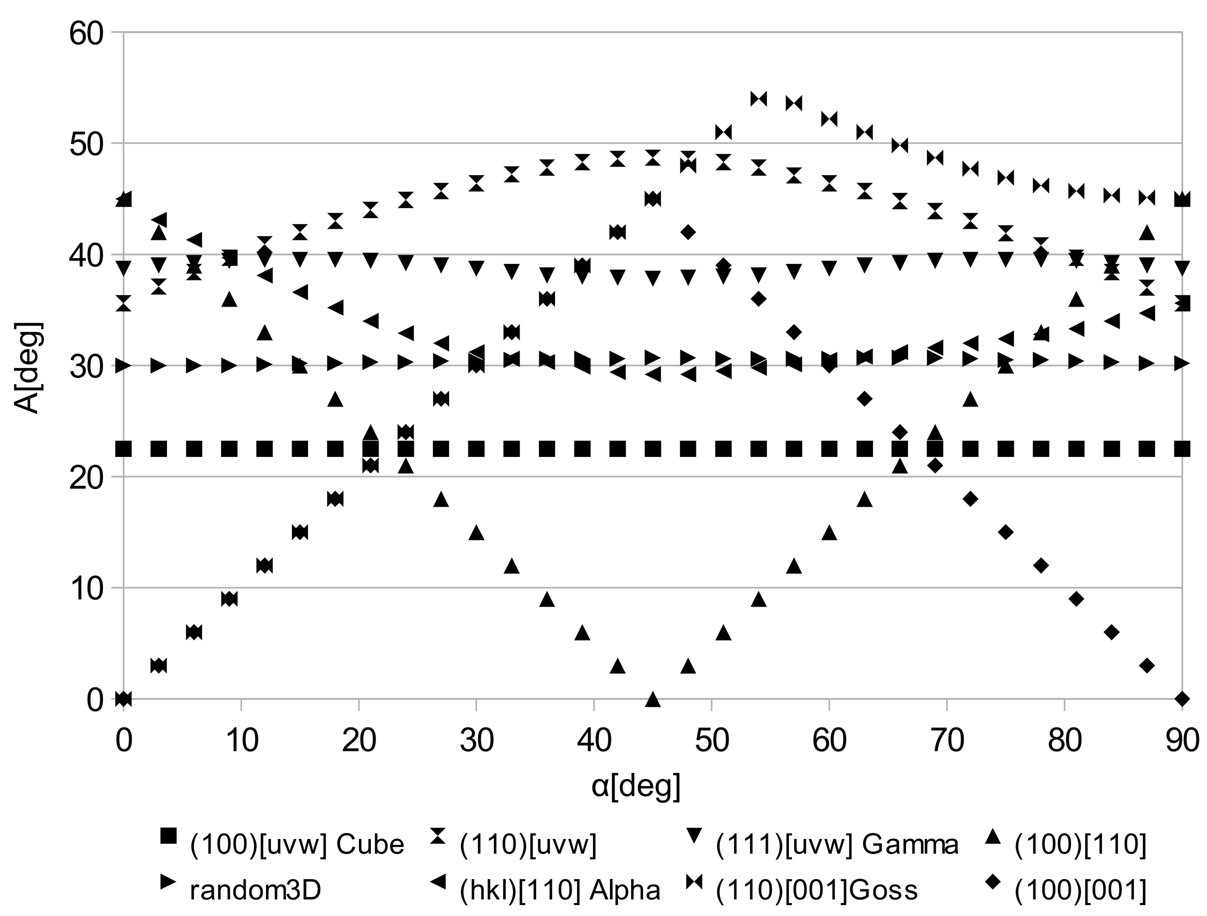

Fig. 1: Parameter A vs. angle for common texture components and fibres.

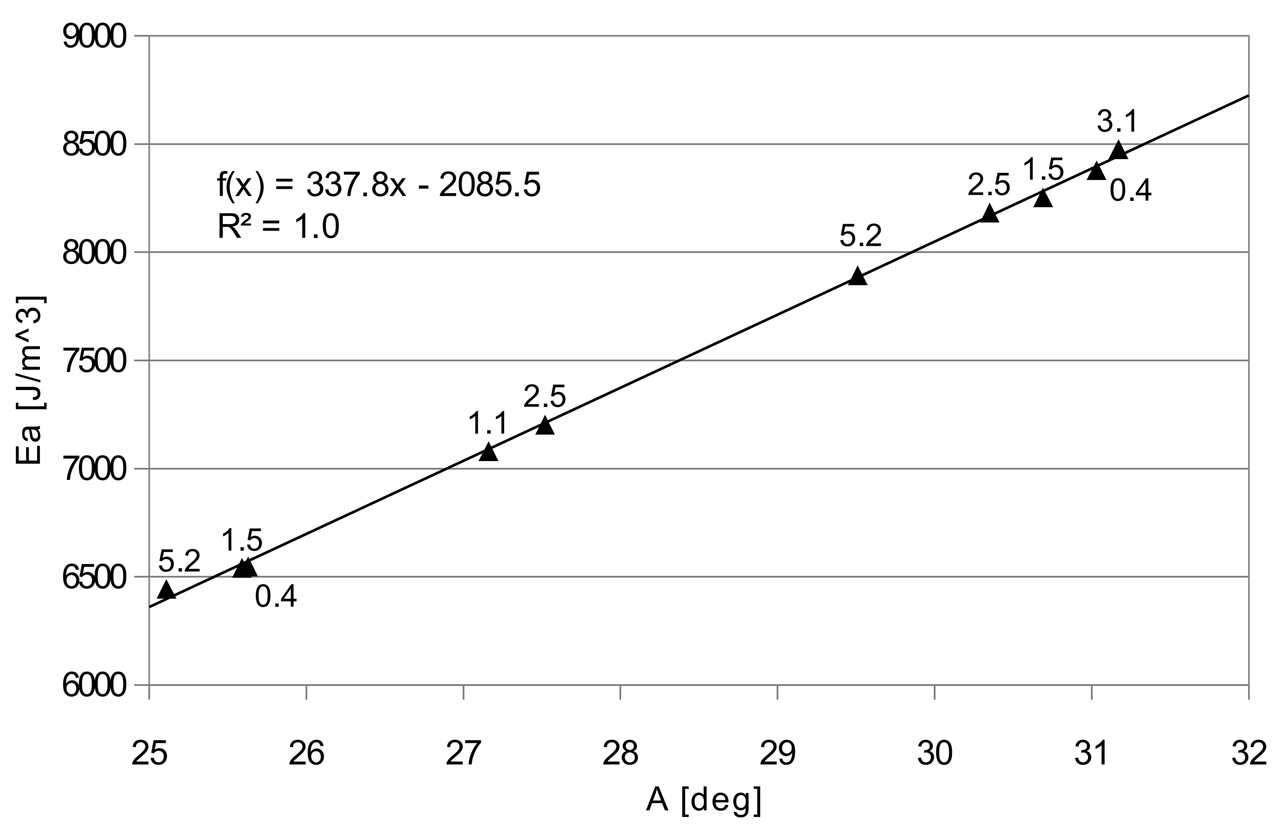

Fig. 2: Magnetic anisotropy energy vs. A at = 0 obtained from ODF for the investigated FeSi materials.

B as Function of A, Grain Size and Si-Content

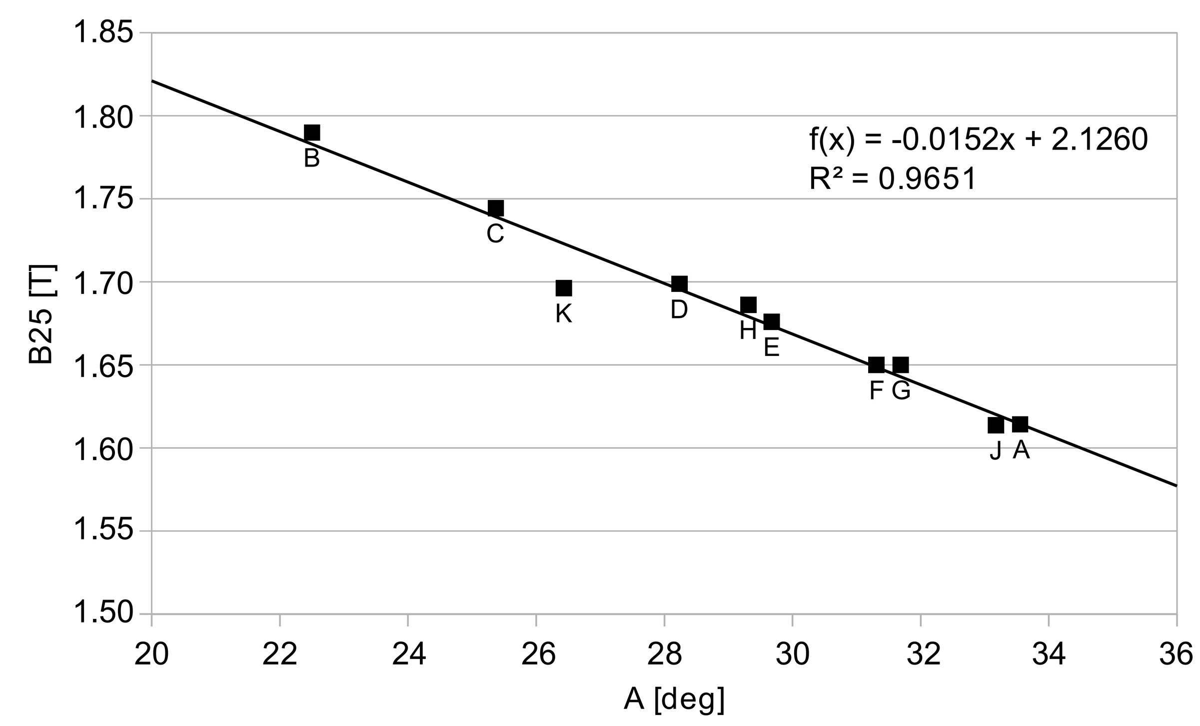

Fig. 3: B25 calculated for mixtures of magnetically relevant magnetic textures (Wiesinger 1985) vs. calculated values of A for these magnetic textures; these values of B25 will be reached in the ideal case that the magnetizing behaviour is only affected by the magnetocrystalline anisotropy.

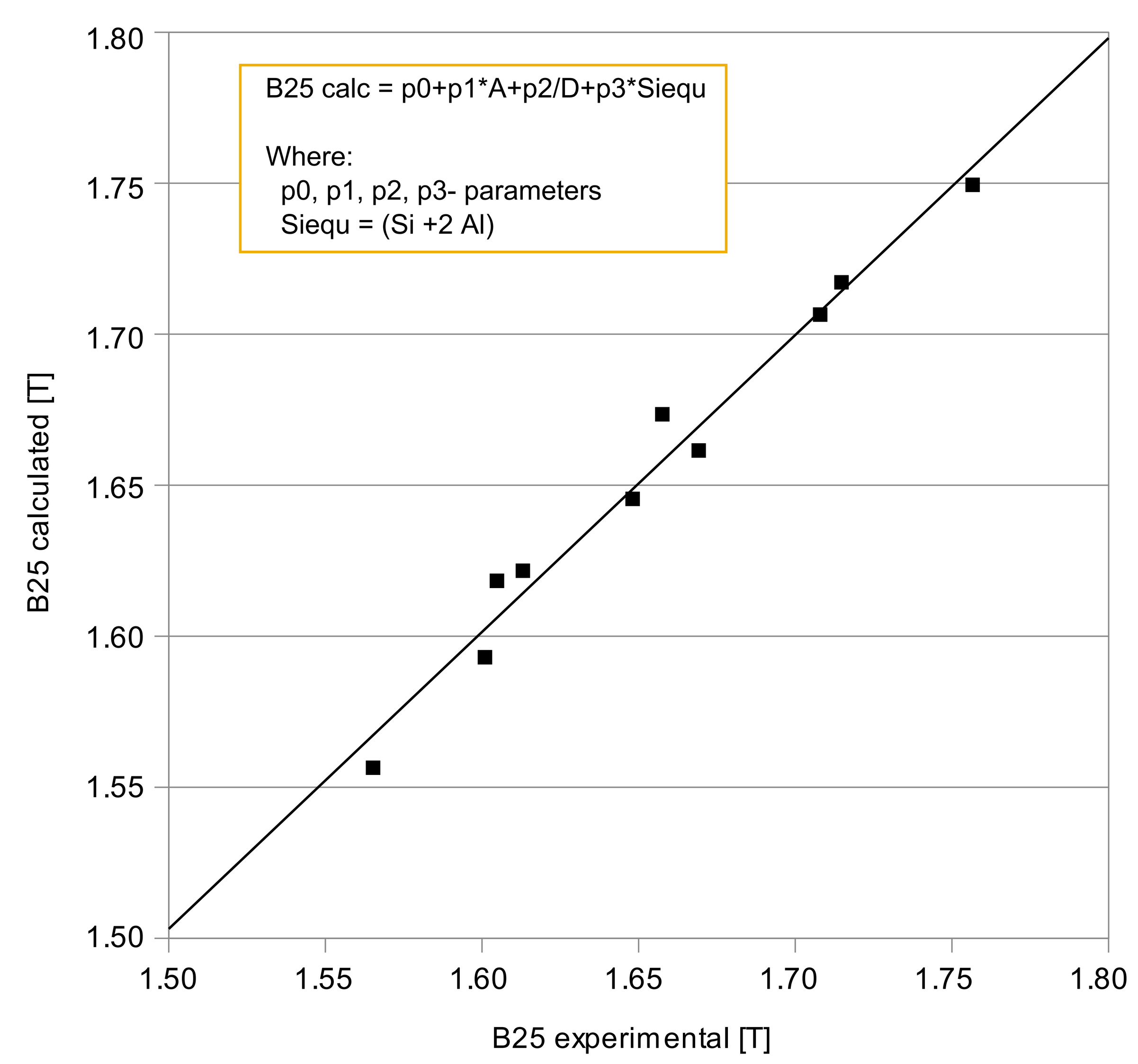

Fig. 4: B25 calc vs. measured for the investigated FeSi materials.

Summary and Conclusions

It was found that the field dependence of the magnetic induction B for commercial electrical steels with variable composition and processing parameters may be well described for H > 300 A/m by taking into account the influence of the crystallographic textures and the grain size. The magnetization behaviour at very high values of the applied field H is mainly determined by the magnetic anisotropy. At decreasing values of the applied magnetic field the effect of the grain size is found to increase.

The validity of the regarded equations seems to be restricted to the region above the maximum value of the permeability max = B / H. In he low field region, where is smaller than max the effect of the microstructural features: grain size, precipitations, and internal stresses on the resulting maximum values of B appears to be more important and has to be analyzed further.