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THE EFFECT OF MAGNETIC INTERACTIONS ON THE MAGNETIZATION OF ORIENTED SHEETS[1])

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The magnetic cooperative interactions between grain oriented FeSi laminations influence the structure of primary and secondary domains of all sheets in a magnetic yoke. Therefore different modes of magnetization take place and some effects of coercivity, power losses, permeability, etc., in sheets are observed.

I. INTRODUCTION

The study of domain structures of grain oriented SiFe materials and their rearrangements upon the application of different physical effects are still of both technological and scientific interest. A general awareness of these domain rearrangements has permitted a gradual improvement in the magnetic properties by the control of metalurgical variables and by other factors which influence the domain structure. One way of iproving the properties of oriented SiFe materials is the domain refinement. The principle of this way is based on the knowledge that domains can be transformed by the residual, or the applied stress and the thickness of lamination, respectively. Strains are formed by the insulation coating and by strain centres created (by scribing or laser) on surfaces of sheets.

The investigation of domains showed a difference between the magnetic structure of a single sheet in comparison with a sheet in a composed magnetic yoke stacked in various ways. Magnetic domains are considerably affected by stacking when the direction of the applied field differs from the roll direction. They are mostly influenced in the case of X stacking, where neighbouring sheets have crossed the rolling directions of one another. The adjacent laminations can influence the domain structure each other only through the magnetic cooperative interactions between both sheets. On the other hand the differences between the domain configuration observed in the case of // stacking, i.e. with parallel

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rolling directions between adjacent sheets, to structure of the single laminations are small. In this case of stacking cooperative interactions are not so significant.

One can see that the convenient type of stacking is also one way of controlling the wall spacing, or the domain refinements.

II. INFLUENCE OF STACKING ON DOMAIN STRUCTURES

In order to discuss the influence of magnetic cooperative interaction on the domain structure in grain oriented SiFe, it has been found convenient to separate the domain structure of a sample into two components, a primary (main) and secondary (supplementary) domain structure. The primary domain structure refers to the large flux carrying slab domains which are separated by 180° domain walls. The secondary structure refers to the remaining structure the flux of which closes the grain boundaries and surfaces on several misoriented grains.

Some quantitative observation of main domain structures of grains in sheets magnetized under different roll angles α for both types of stackings was already published [1]. These investigations show that magnetic cooperative interactions are accomplished by several changes in the main domain configurations and the magnetization process. For example, the differences in the arrangement of the slab domains are evident for different types of stacking. The crossing stacking supports the ovement of the 180° walls, reduces pinning and changes the spacing of walls. Some immovable walls in a single sheet become movable in an X stacking. In sheets magnetized under angles $\alpha > 52°$ with respect to the rolling direction the magnetization takes place through a different rearrangement of the slab domains for both types of stacking. In a weak applied field magnetization takes place through a slight displacement of the 180° domain walls for the X stacking.

Secondary structure occurs in order to reduce the magnetoelastic energy on surfaces or grain boundaries. This structure is formed by transverse domains which are flux closed on the sheet surfaces. Transverse domains carry a component of flux normal to the top and bottom sheet surfaces as well as normal to the sheet surface. Due to magnetic cooperative interactions between sheets considerable changes occur in the supplementary structure.

The quantitative observations were made on secondary domain structures of grains in several sheets magnetized at different angles α with regard to the rolling

Fig. 1. Photographs showing the changes of a secondary domain structure due to magnetic cooperative interactions between oriented sheets with $\alpha = 45°$: (a)—(c) demagnetized state; (d)—(f) magnetized under applied field 460 A/m; (a), (d) — one sheet; (b), (e) — 2 sheets // stacking; (c), (f) — 2 sheets X stacking the Bitter technique was used.

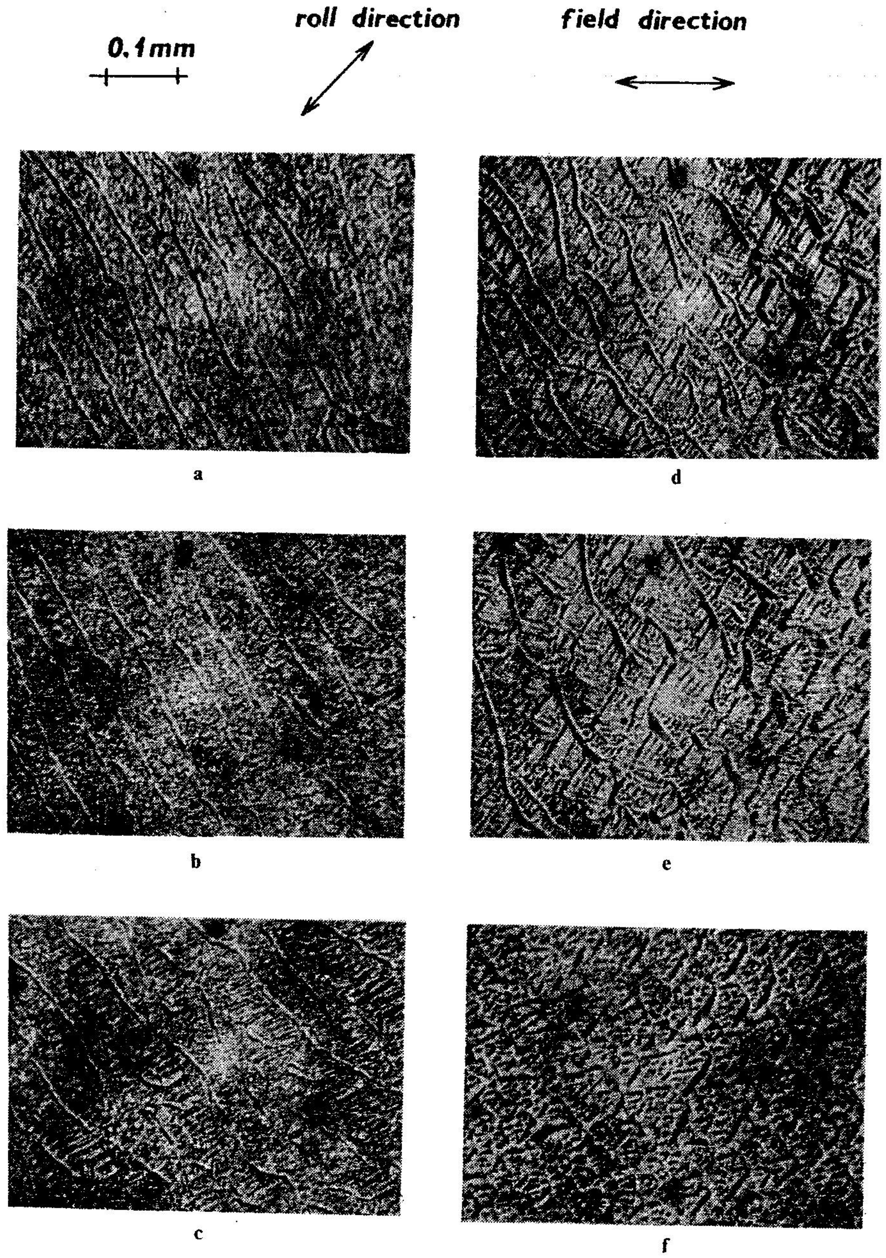

fig. 1

direction for both types of stacking. First there was observed the domain structure in one sheet for any α, then the observed sheet was covered by another with // and with an X type stacking, respectively. The samples used were prepared from oriented FeSi steel in laminated form of standard size (280 × 30 × 0.35 mm) and were cut at different angles with respect to the rolling direction.

For example, changes of secondary domains on the grain surface in sample with $\alpha = 45°$ are illustrated in Fig. 1. The direction [001] of the grain is tilted out of the sheet plane under the angle $\delta \doteq 8$. Photograph (a) shows a roughly aligned lancet comb structure in a demagnetized sheet. For the // stacking of two sheets the spacing of the comb lines is spread out and the lacent domains are prolonged. If X stacking (photograph (c)) were used the aligned structure is destroyed. The lancets are still more prolonged. There are considerable differences of secondary domain structures between the // and the X stackings.

The photographs (d)—(f) illustrate the changes of a supplementary structure in a relatively strong magnetic field for one sheet and two sheets with both types of stacking. Bigger changes of these domains for a different stacking of sheets are observed i a applied magnetic field than in the demagnetized state.

III. SECONDARY EFFECTS DUE TO MAGNETIC COOPERATION

Magnetic cooperative interactions between grain oriented FeSi sheets influence the configuration of both primary and secondary domains of each individual sheet in a magnetic yoke. Therefore different modes of magnetization processes take place for both stackings. Further variations of domain configuration and magnetization processes will influence the extrinsic magnetic properties of sheets in the stack. In consequence of that a series of secondary effects is evoked by magnetic cooperative phenomena, e.g. coercivity effects, loss effects, permeability effects, ambiguity of the Mössbauer spectra, etc.

The coercivity H_c of grain oriented SiFe material considerably rises with a deviation of the applied field from the roll direction and due to magnetic cooperations is strongly affected by the type of stacking. The coercivity varies with the number of laminations in the stack and it also depends on the distances between neighbouring sheets mainly for the X stacking. The magnitude of H_c varies with the number and the location of the crossing of directions between the adjacent sheets in the stack.

Losses in grain oriented SiFe laminations again depend on the roll direction and the stacking of sheets [2, 3, 4], on the number and the distances between sheets, etc. Because the total core losses depend on the domain wall spacing and the wall mobility we must distinguish two types of loss effects, the static hysteresis and the dynamic loss effects, respectively. In contrast to the dynamic loss effects the static one have qualitatively the same character as the coercivity effects.

Permeability effects occurred due to magnetic cooperative interactins in a magnetic yoke and have a more complicated character than losses effects. In addition, in this case we must ditinguish between effects in accordance with the kind of permeability and the magnetic state chosen.

The magnetic cooperative phenomena in the stack of laminations were an important reason of the measured influence of the stacking on core losses [2, 3], on coercivity [5, 6], on permeability [7], on the ambiguity of the Mössbauer spectra [7] etc.

IV. CONCLUSIONS

The investigation of the domain structure changes shown the existence of magnetic cooperative interactions between grain oriented FeSi sheets in the stack. These interactions are the reason of a lot of secondary effects of extrinsic magnetic properties which occur in the sheets. For one type of stacking X the cooperative interactions influence negatively the stabilization of domains and walls.

Many important magnetic properties of grain oriented materials are derived from rearrangements of magnetic domains. One way of improving the extrinsic magnetic properties of these materials can be to utilize the magnetic cooperative interactions. A convenient type of stacking is one of the way to control the domains, for example. Another way for controlling the domains due to magnetic cooperations can be the regulation of distances between sheets.

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ВЛИЯНИЕ МАГНИТНЫХ ВЗАИМОДЕЙСТВИЙ НА МАГНЕТИЗАЦИЮ ОРИЕНТИРОВАННЫХ СЛОЕВ

Магнитные кооперативные взаимодействия между текстурованными FeSi расслоениями обуславливают структуру первичных и второчных доменов всех слоев в магнитном ярме. Поэтому появляются разные моды магнетизации; в слоях также наблюдаются некоторые эффекты, такие как коэрцитивность, потери мощности, проницаемость и т. д.