Polycrystalline Magnetic Field Analysis of Electrical Steel for Magnetic Multi-Scale

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Electrical steel is mainly used for electrical motor core or transformer due to high magnetic performance and mass production technology. It is polycrystalline material where each crystal has some magnetic domain with saturated magnetization. So it is said to be an important role between magnetic domain and electrical motor in magnetic multi-scale problem. Usually its calculation model of magnetic analysis should be carried out by magnetic domain model such as LLG or so. However, since electrical steel of polycrystalline has a lot of magnetic domains, when all the magnetic domains are considered for numerical calculation, mesh explosion problem will occur. So the polycrystalline of electrical steel should be modeled to avoid it. Here, static magnetic field analysis in finite element method is used for it in some assumptions that equivalent magnetic material constants are used in homogenized method and coordinate transform of magnetic flux density is used[1-3].

Figure 1 shows total coordinates in polycrystalline and local coordinates in each crystal. Magnetic anisotropy of each crystal is expressed in local coordinate and continuity of magnetic flux density is expressed in total coordinate[4]. So the coordinate transform between them is carried out. GO (grain oriented steel) material with 56 crystal grains in 80 mm^2 square are used for calculation in comparison with the measured magnetic property. Crystal orientations as α, β, γ angles defined in Fig. 1 are well organized and they are centralized within several degrees in average.

Figure 2 shows comparison of magnetic flux density distribution between 3D polycrystalline magnetic field analysis and distributed magnetic measurement[4]. Fig. 2 (a) is measured magnetic flux density by needle method with some square and Fig. 2 (b) is calculation one where magnetic flux density distribution as Fig. 3 (c) is averaged in some square of the needle method. The calculation result well expresses the measured one.

Figure 3 shows comparison of inclination angle of magnetic flux density vector $\vec{B}$ between 3D polycrystalline magnetic field analysis and distributed magnetic measurement[4]. Fig. 3 is the calculated inclination angle which is an angle between the easy magnetization direction of the polycrystalline and the magnetic flux density vector, and Fig. 3 (b) is α angle of each crystal grain. Magnetic flux density is expected to flow in polycrystalline in order to follow each crystal orientation. So angle distribution of Fig. 3 (a) and (b) are in good agreement.

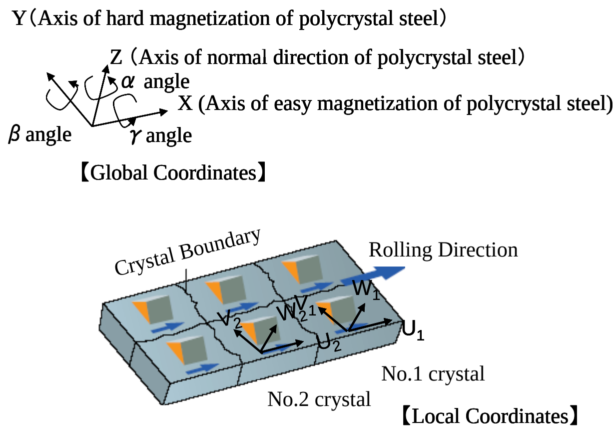
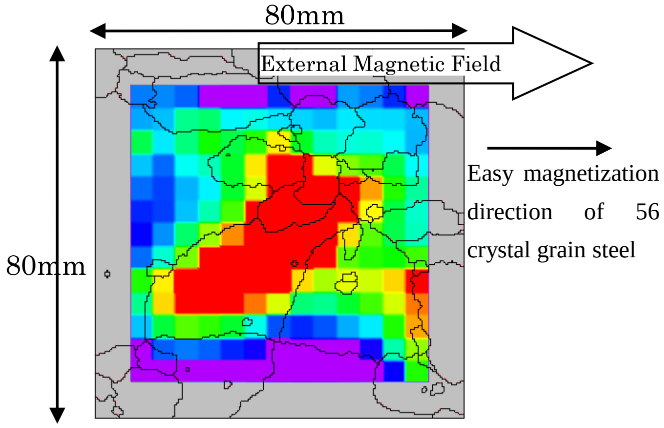
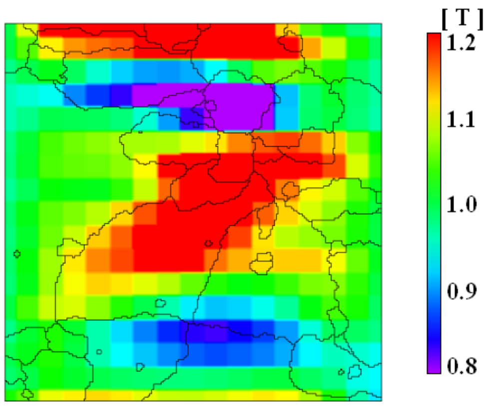


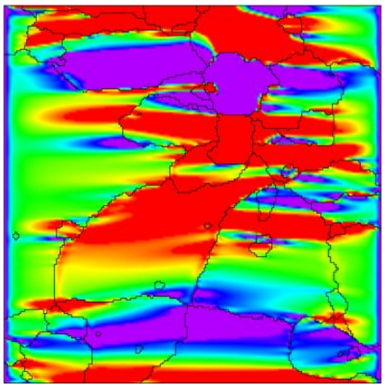
Fig.1. Total coordinates and local coordinates for polycrystalline magnetic field analysis.



(a) Distributed magnetic measurement.

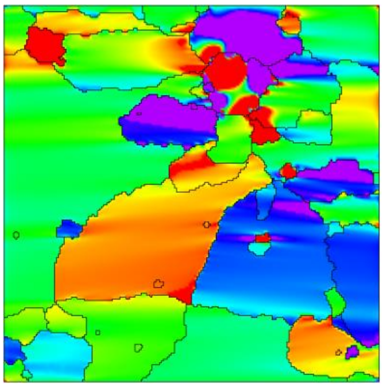


(b) 3D polycrystalline magnetic field analysis (revised for distributed magnetic measurement).

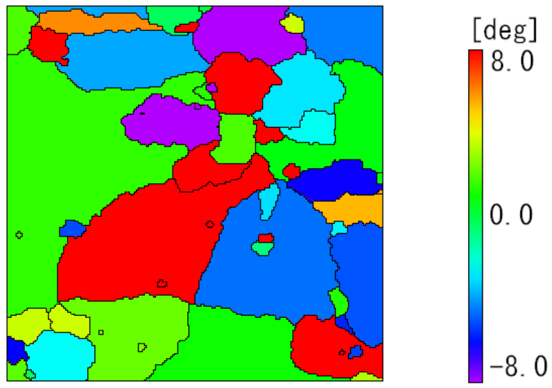


(c) 3D polycrystalline magnetic field analysis (original).

Fig.2. Comparison of magnetic flux density distribution between 3D polycrystalline magnetic field analysis and distributed magnetic measurement in 56 crystal grains GO specimen



(a) 3D polycrystalline magnetic field analysis



(b) α angle distribution.

Fig.3. Comparison of inclination angle of magnetic flux density vector $\vec{B}$ between 3D polycrystalline magnetic field analysis and distributed magnetic measurement in 56 crystal grains GO specimen.

Reference

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