Some approaches for estimating thermal residual stresses in a polycrystalline $Nd_2Fe_{14}B$ magnet

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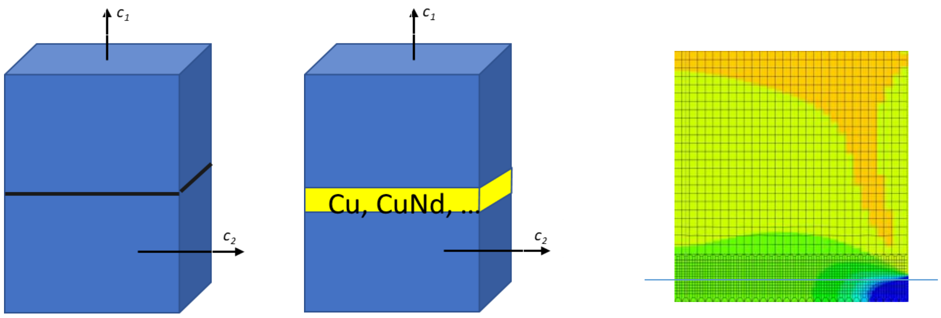
Grain boundaries and interfaces are of utmost importance for the coercivity of NdFeB-based magnets [1]. The interplay between the local intrinsic magnetic properties and magnetization processes at the nanoscale determines coercivity. Strain fields change the local magnetocrystalline anisotropy of permanent magnets. Because magnetization reversal starts from the surface of the grain, the local strain at a distance from the interface that is comparable with the exchange length (~ 2 nm) are important. The contribution of thestrain (ε_{ij}) to the anisotropy can be approximated as follows [2]:

$$\Delta K = -b_{12}\left(\varepsilon_{xx} + \varepsilon_{yy}\right) - b_{22}\varepsilon_{zz},$$

where K is the uniaxial magneto-crystalline anisotropy constant, b_{ij} are the magnetoelastic coupling constants.

In our local problem we consider a polycrystal neodymium magnet with and without an intergranular phase of another material. And in the following we will study the influence of physical and mechanical properties of the intergranular phase, the layer thickness of this phase, the crystal orientation of both the matrix and the intergranular phase and the temperature factor on the residual stresses. The thermal expansion coefficients and elastic constants of $Nd_2Fe_{14}B$ are anisotropic. After cooling from the sintering temperature, misaligned grains in direct contact will be subject to high residual thermal strain (Figure 1). Similarly, the difference in the thermal expansion coefficients between the main $Nd_2Fe_{14}B$ phase and the grain boundary phase may cause a residual strain in $Nd_2Fe_{14}B$ near the interface after cooling. For a quantitative analysis of the residual thermal strain, thermal expansion coefficient and the Young's modulus parallel to the interface are important. These values depend on the orientation of the crystals with respect to the interface. For simplified geometries the residual thermal strain and the misfit strain can be computed analytically. The thermal strain in $Nd_2Fe_{14}B$ increases linearly with the difference in thermal expansion coefficients, the sintering temperature, and the Young's modulus of the grain boundary phase. The residual strain in $Nd_2Fe_{14}B$ is inversely proportional to the thickness of the grain boundary phase.



a) b) c)

Figure 1: The simplest cases of interaction of 2 crystals oriented in different directions a) without intergranular phase; b) with intergranular soft phase; c) modelling by OOF2.

We compare analytic solution with FEM simulation using OOF2 (https://www.ctcms.nist.gov/). Similar results have been obtained.

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References

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