A numerical study on $Nd_2Fe_{14}B$ magnets produced by severe plastic deformation

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The renewable energy supply, the independence of fossil resources, as well as the change in mobility act as a driving force on technological innovation. To meet these challenges of our time, new and particularly powerful high-performance magnets are necessary [1], relying on new earth abundant materials and resource efficient processes. It has been shown that composite materials consisting of ferromagnetic grains separated by paramagnetic interphases can contribute to significant improvements in coercivity, when these interphases decouple the magnetic exchange between the individual grains, compare [2]. Novel processing routes based on severe plastic deformations (SPD) or additive manufacturing (AM) can be an option to tailor such magnetic composites. Here, the micromagnetic theory can be applied to numerically predict the magnetization distributions on fine scales. Due to their flexibility, finite elements are well suited to discretize and analyze strongly heterogeneous microstructures [3]. The evolution of the magnetization vectors is described by the Landau-Lifshitz-Gilbert equation, which requires the numerically challenging preservation of the Euclidean norm of the magnetization vectors, see [4,5]. With the aim to correctly reproduce the behavior of magnetic materials, competing energy contributions are considered within the energy functional, which are also responsible for the formation of magnetic domains. Also, grain boundaries, defect layers

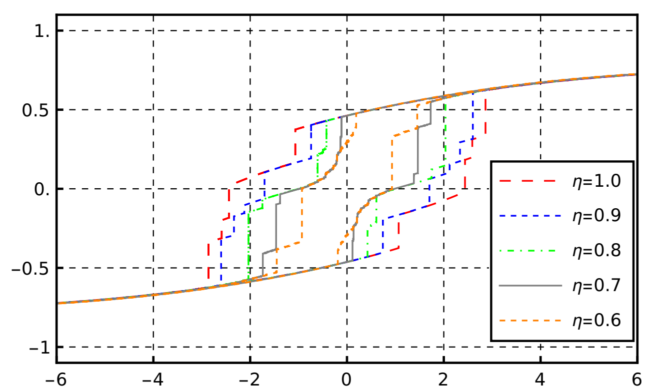

Figure 1: Hysteresis loops for differently pronounced surface defects $K^{\rm sur} = \eta\, K^{\rm ani} \,|\, \eta \in (0,1)$, where η is a defect factor relating the defect intensity to the crystalline anisotropy.

and misoriented grains can have a huge impact on the macroscopic hysteresis behavior of magnetic materials, as presented in Fig. 1. Especially magnets formed by SPD are exposed to the potential stress-induced defects that might outweigh their production benefits. Hence, micromagnetics analyses are performed to estimate the risks and challenges of these novelties.

References

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