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Recent Advances in the Numerical Simulation of Hysteresis Curve

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ABSTRACT

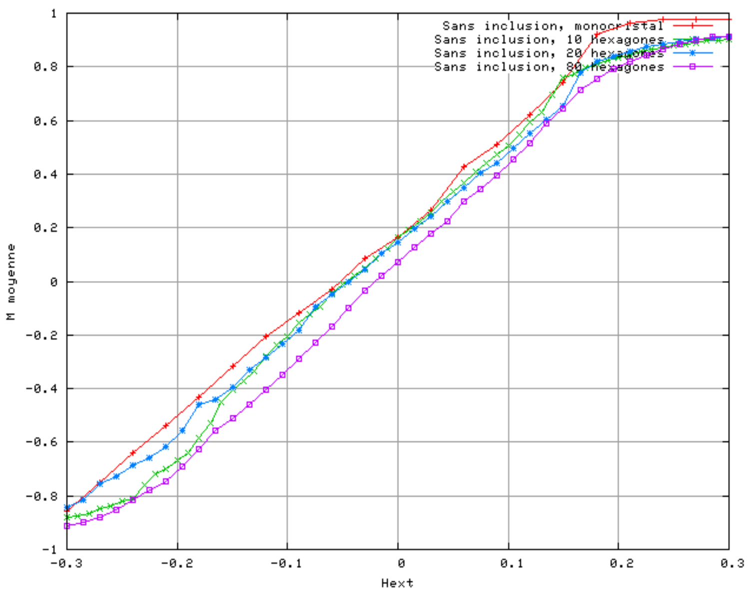
Magnetic properties are known to provide a great deal of information about the micro structural state and the mechanical behavior of ferromagnetic materials (e.g. density of dislocations, grain size, inclusions, and applied or residual stresses). Consequently, magnetic characterization of steels is of high industrial interest in the quality control process; it can help designing non-destructive magnetic measurements to provide a snapshot of the material.

In a ferromagnetic material, the magnetization field has fixed orientations upon elementary sub domains separated by thin walls so that we obtain magnetic domains. The numerical simulation of this phenomenon is based on the minimization of an energy function, which adds the crystalline anisotropy, spin exchange, and magnetostatic energy contributions. In convenient functional spaces, it can be proved that this minimization problem has non unique solutions due to various possible local minima of the function and to different possible distributions of magnetic domains. The approximation of this minimization problem combines iterative method like conjugate gradient methods with finite element methods. In previous works, some numerical experiments were carried out on a reduced two-dimensional sample. They qualitatively illustrate phenomena such as the magnetic domains and moving walls under a varying external field. They are qualitatively in good agreement with microscopic observations.

In this presentation, we consider more specifically the case of ferromagnetic polycrystalline sample composed of several hexagons. We are interested in the effect of the grain size on the hysteresis curves and the effect of some non magnetic defaults on the magnetic configuration of the domains and on the hysteresis curve. The experiments

show the complexity of magnetic domains and walls inside of ferromagnetic materials. Thus, the elements of the mesh have to be sufficiently small to describe such a micro structure. The major problem is that if we use standard discretization methods, the number of the elements becomes so high that we can't have numerical results in a reasonable time. That's why we use an adaptative mesh. As the computation is done on a mesh which combines elements from different scales (it is not the case with standard methods as the finite element method or the finite difference method), we have to adapt the methods that compute the different terms of energy.

To validate our finite element model, we have made several series of numerical experiments. For example, we have considered a 74µmX45µm sample with different grain sizes. We find below the hysteresis curve, where we can see that these curves have almost the same slope while the coercive field is different.



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