Micromagnetic calculations of eddy currents with time-varying fields

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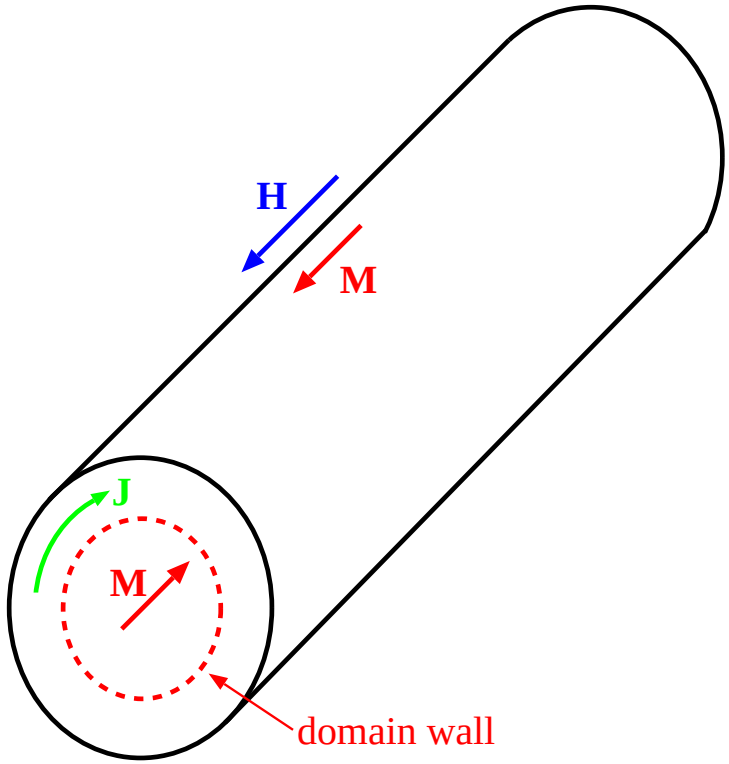
Abstract

This work describes the effects of a time varying applied magnetic field on magnetic domain wall motion and eddy currents in an infinite conducting cylinder.

The simulation is based on a previously presented program[1,2] designed for a limited geometry and intended to provide computational results for testing more complex programs[3−5].

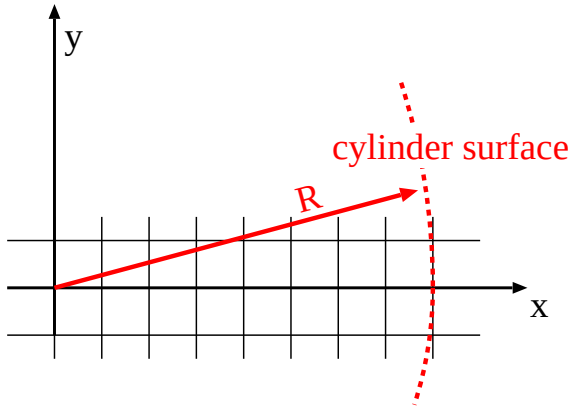
Problem overview

1. Initial **M** parallel to cylinder axis.
2. Oppositely directed **H** nucleates concentric Bloch wall on cylinder surface.
3. Wall propagates towards center.
4. Wall motion generates eddy currents **J**, which oppose wall motion.



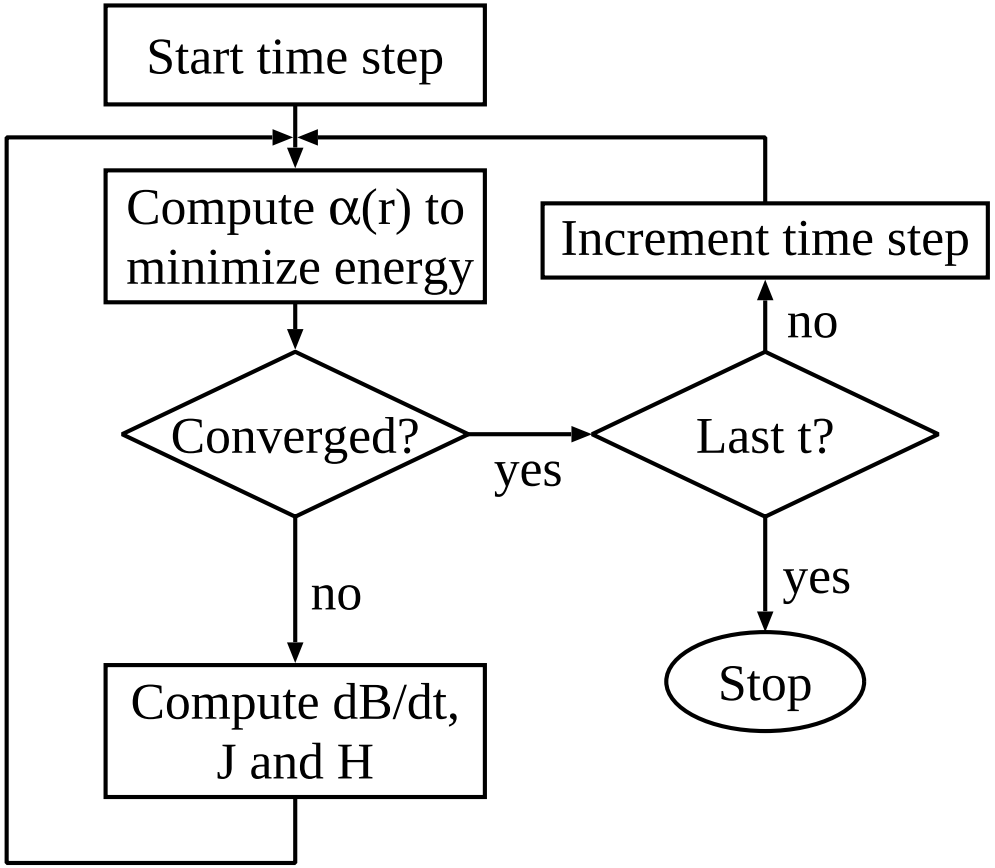
Program overview

- One dimensional problem, $\mathbf{M} = \mathbf{M}(r)$.
- Coupled magneto/electro-dynamic system solved by interleaving micromagnetic and eddy current computations.

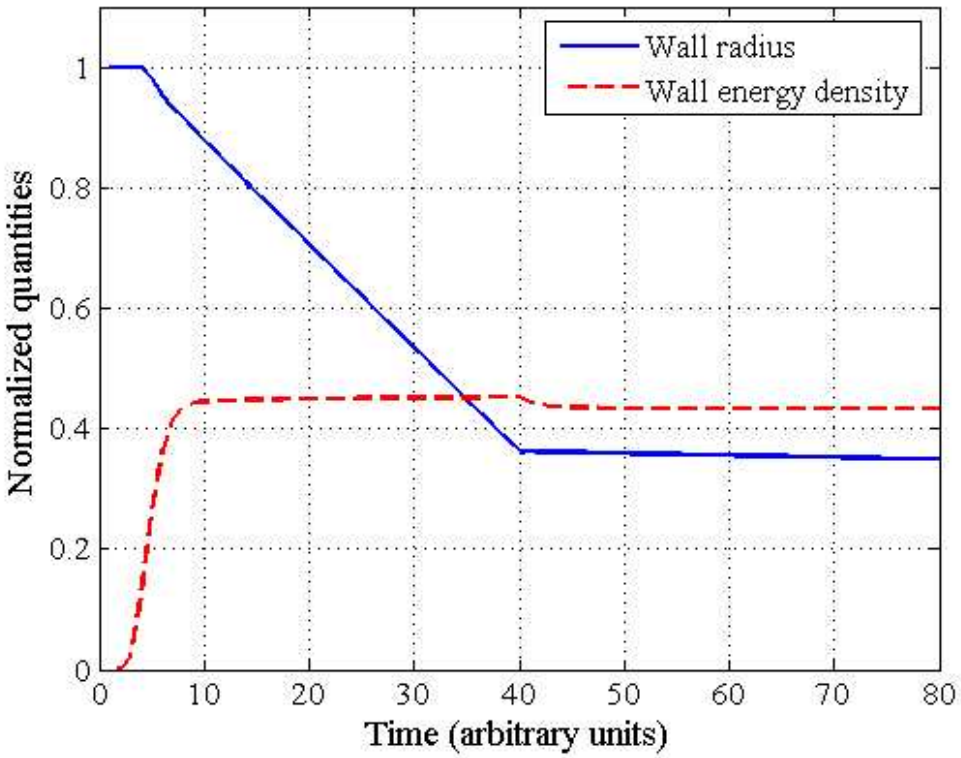


- Magnetic dynamics assumed much faster than eddy current relaxation; micromagnetic steps handled by direct energy minimization.
- No precession + problem geometry $\Rightarrow$ no demag.
- Energies: magnetostatic (applied + eddy current), magnetocrystalline anisotropy, exchange.

Program flowchart

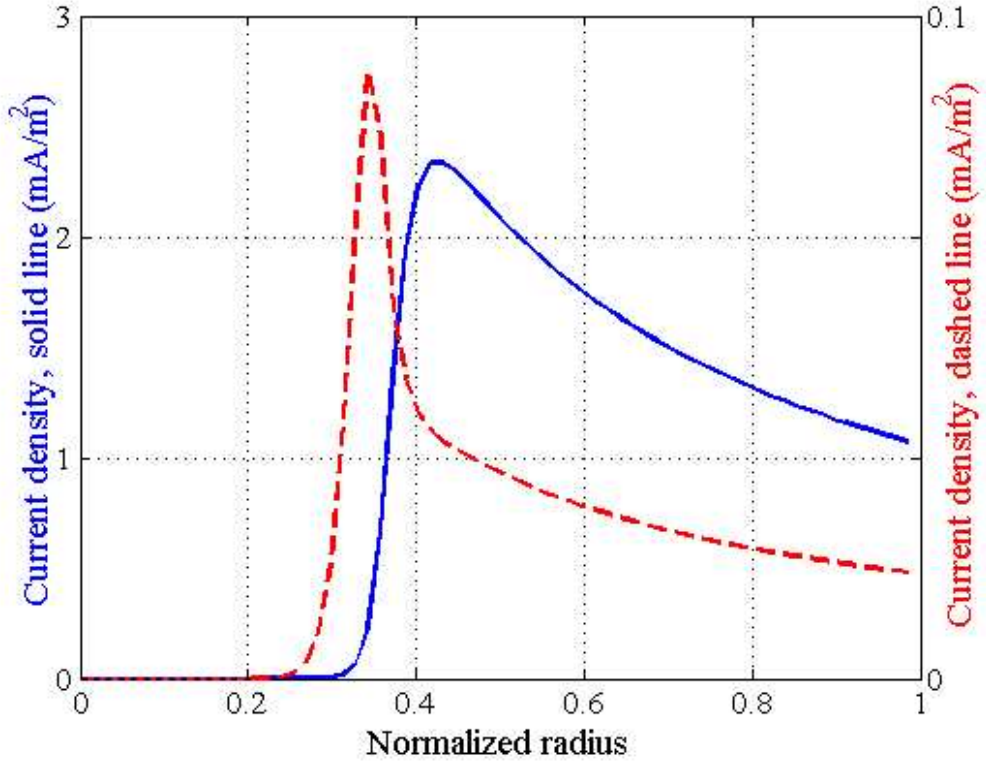


Field pulse



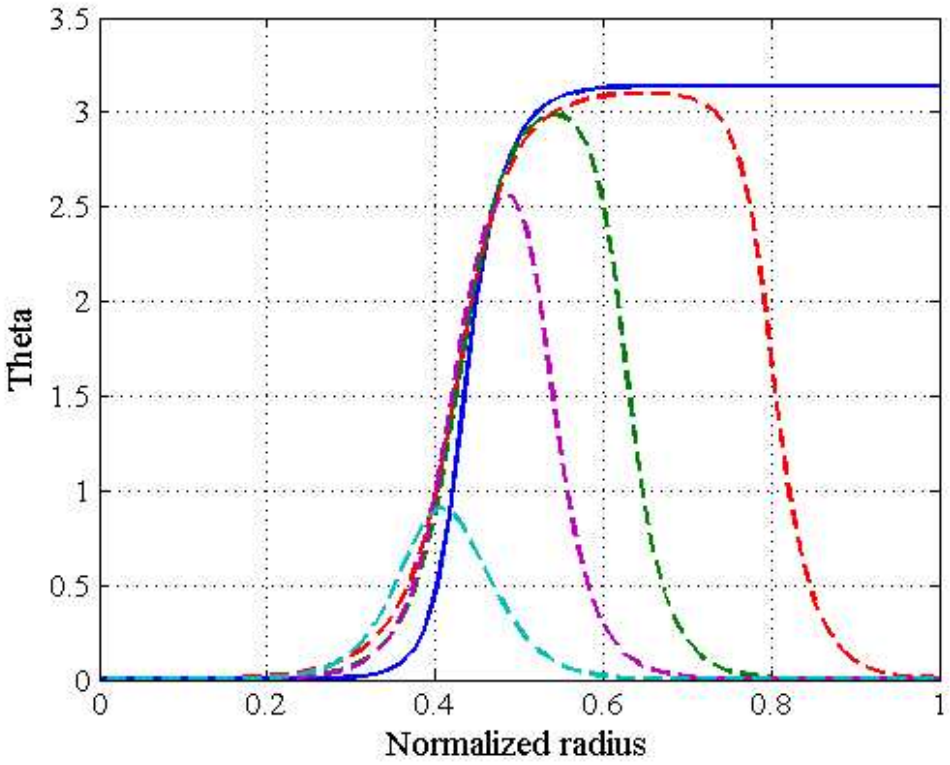
Response from field pulse of duration 40 units.

Field pulse



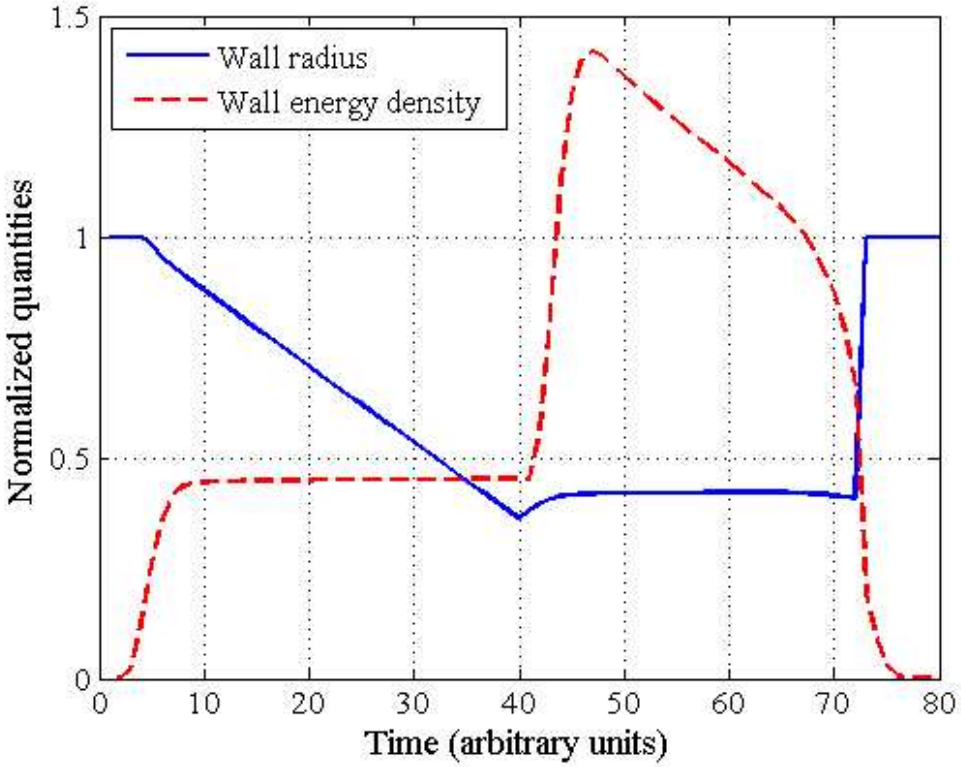
Current density just before (solid) and after (dashed) end of pulse.

Square wave



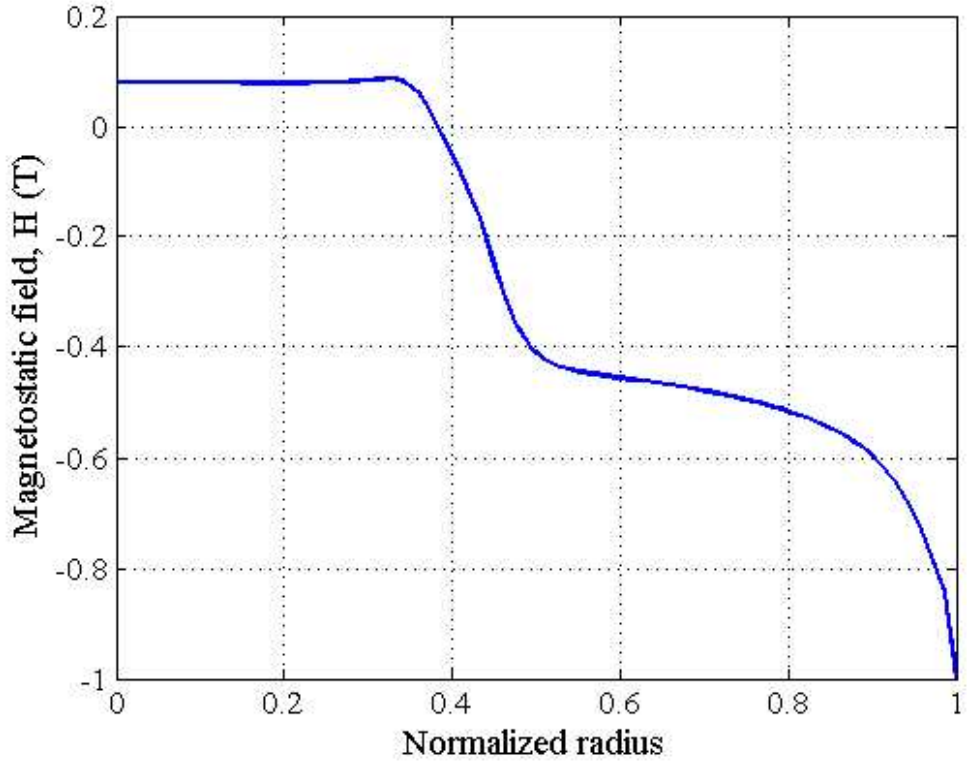
Magnetization angle before (solid) and after (dashed) field reversal; two walls annihilate.

Square wave



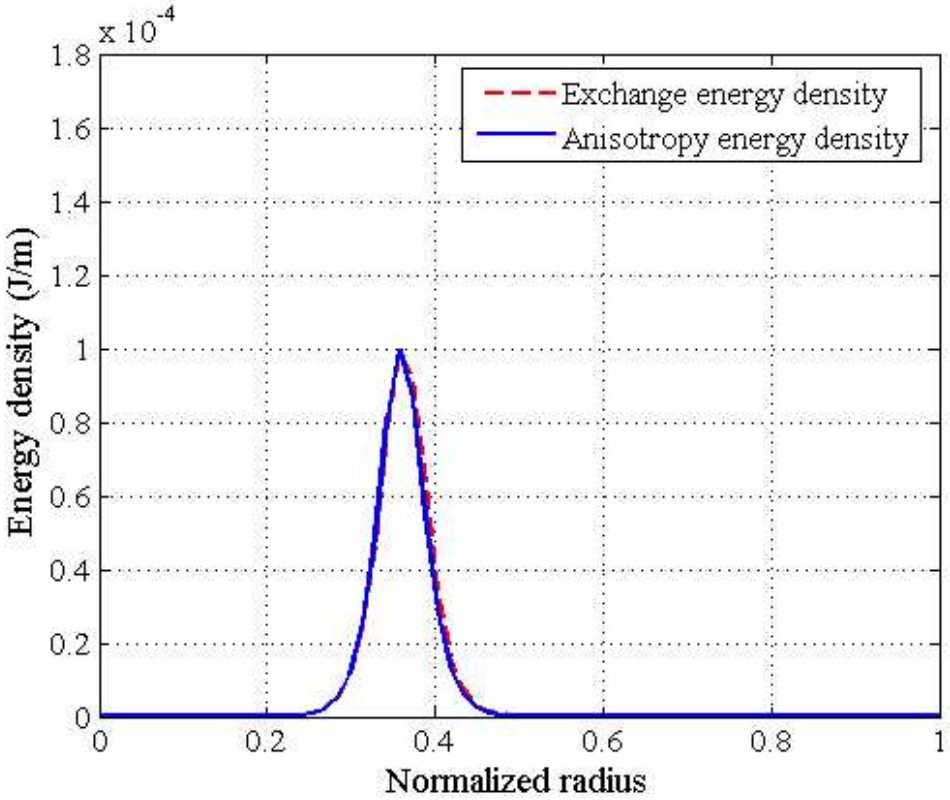
Inner wall response to field reversal at time 40.

Square wave



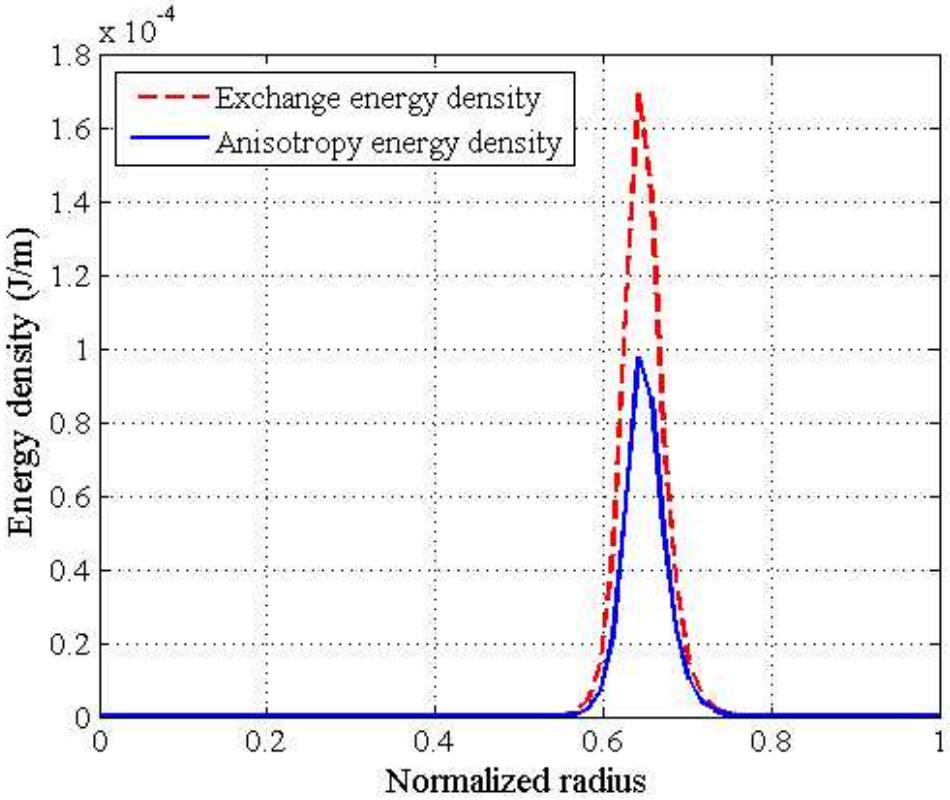
Magnetostatic field ($\mathbf{H}_{\mathrm{app}} + \mathbf{H}_{\mathrm{eddy}}$) just after field reversal.

Energy profiles



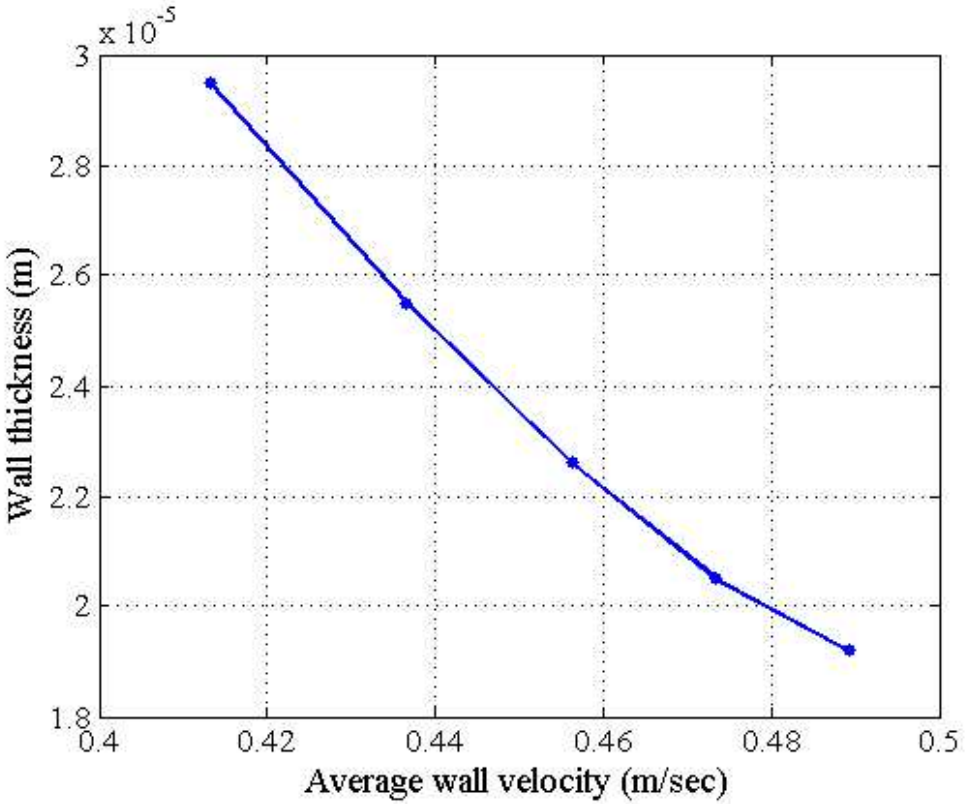
Energy components with $\mathbf{H}_{\text{app}} = 0$.

Energy profiles

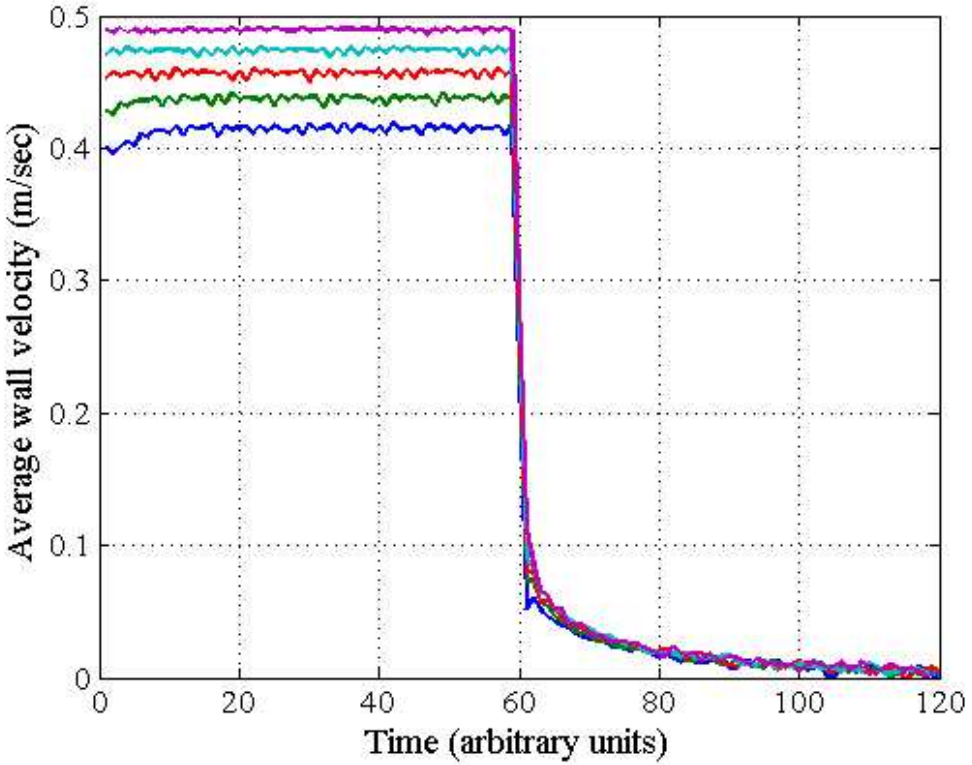


Energy components for moving wall ($\mathbf{H}_{\text{app}} \neq 0$).

Wall width

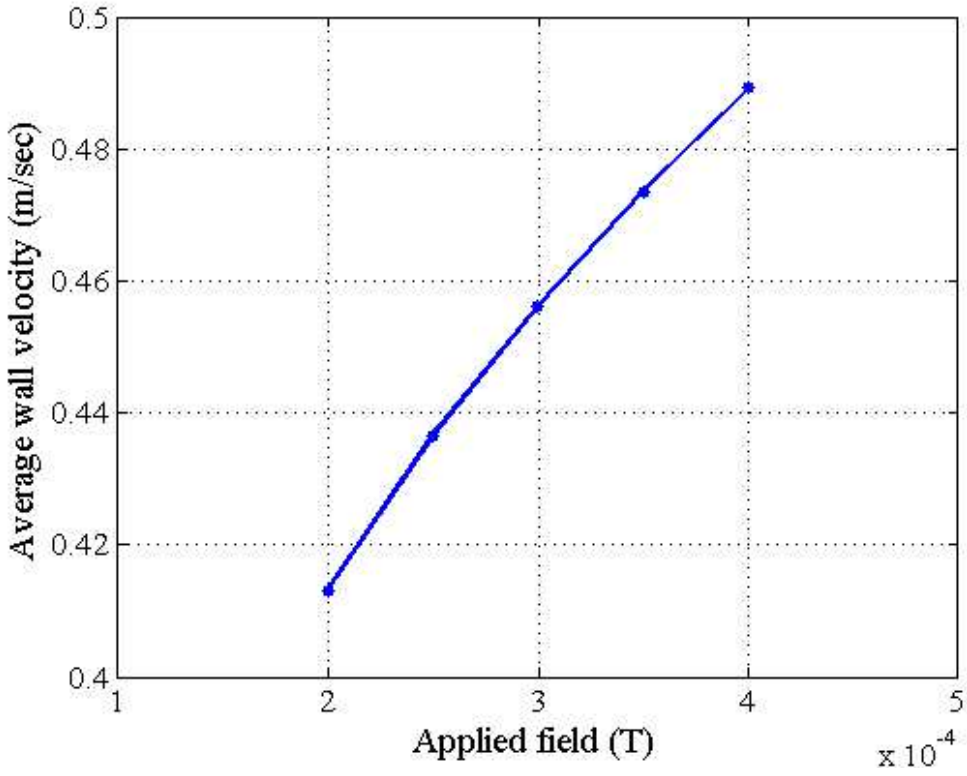

x 10^-5
3
2.8
2.6
2.4
2.2
2
1.8
Wall thickness (m)
0.4
0.42
0.44
0.46
0.48
0.5
Average wall velocity (m/sec)

Wall velocity



Applied fields (from bottom):
0.2, 0.25, 0.3, 0.35, 0.4 mA/m.

Velocity vs. field



Summary

- Wall motion slows by orders of magnitude when applied field is removed, but does not completely stop.
- Reversing applied field nucleates opposite wall which propagates inward and annihilates previous wall.
- Exchange/anisotropy energy ratio =1 for stationary wall, >1 for moving wall.
- Wall width shrinks with increasing velocity.
- Wall velocity depends non-linearly on applied field.

References

1. L. Yanik, E. Della Torre, M. J. Donahue, "A test bed for a fi nite difference time domain micromagnetic program with eddy currents," *Physica B*, **343/1-4**, 216-221 (2004).
2. L. Yanik, E. Della Torre, M. J. Donahue, E. Cardelli, "Micromagnetic eddy currents in conducting cylinders," *J. Appl. Phys.*, **97**, 10E308 (2005).
3. L. Torres, E. Martinez, L. Lopez-Diaz, O. Alejos, "About the inclusion of eddy currents in micromagnetic computations," *Physica B*, **343/1-4**, 257-261 (2004).
4. J. Fidler, T. Schrefl, W. Scholz, D. Suess, R. Dittrich, M. Kirschner, "Micromagnetic modelling and magnetization processes," *J. Magn. Magn. Mat.*, **272-276**, 641-646 (2004).
5. Sandler, G.M., Bertram, H.N., "Micromagnetic simulations with eddy currents of rise time in thin fi lm write heads," *J. App. Phys.*, **81**, 4513-4515 (1997).