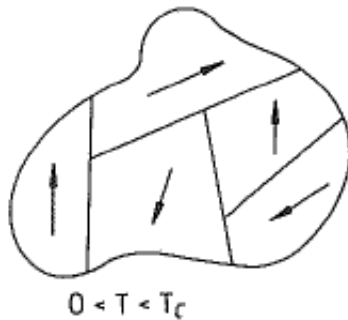


Theory of the Barkhausen Effect and the Microstructure of Ferromagnetic Materials

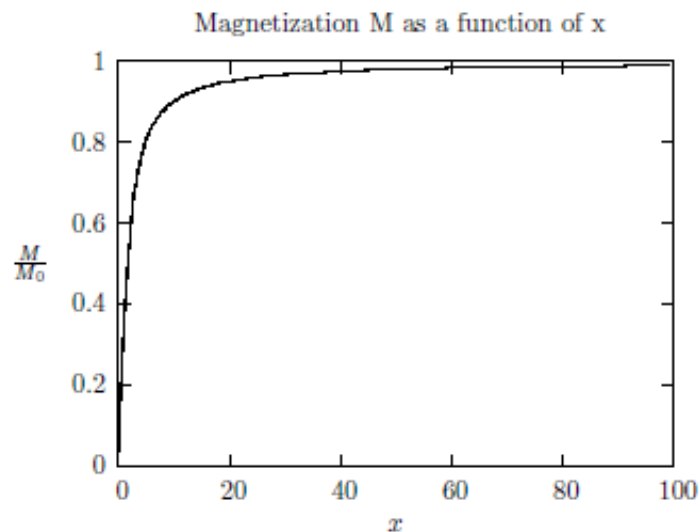
- Table of Contents
- (1) Introduction
- (2) Theory
- (3) Results
- (4) Conclusions

- Barkhausen effect: The magnetization $M(H)$ of a ferromagnetic material changes in small finite steps. This is due to the existence of ferromagnetic domains.

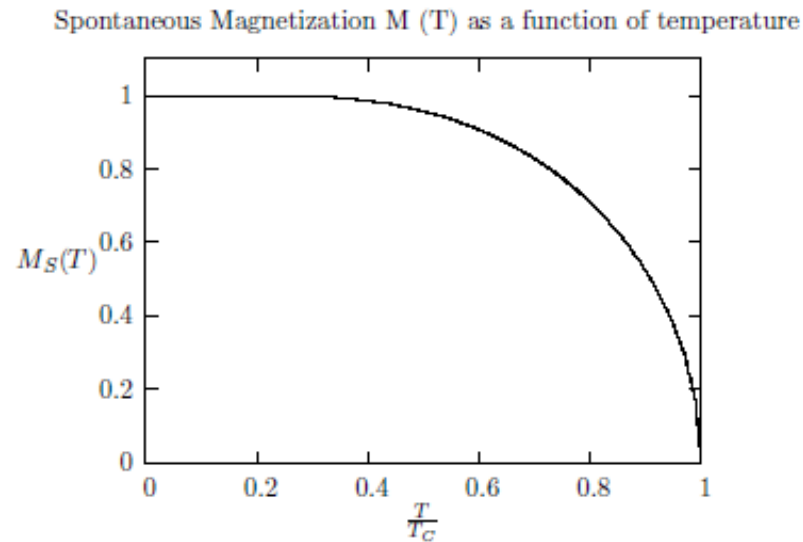


- Experimental evidence regarding the correlation between magnetic Barkhausen noise and domain wall motion was presented at the WCNDT conference of 2016 and is obtained with methods, e.g.
- -magneto-optical Kerr effect
- -magnetic force microscopy
- -scanning electron microscopy.
- It also serves as a useful NDE technique.
- However, this presentation is restricted to the corresponding theory.

- Standard models of magnetism give qualitatively satisfactory results for the magnetization $M(T, H)$ of a ferromagnetic material.



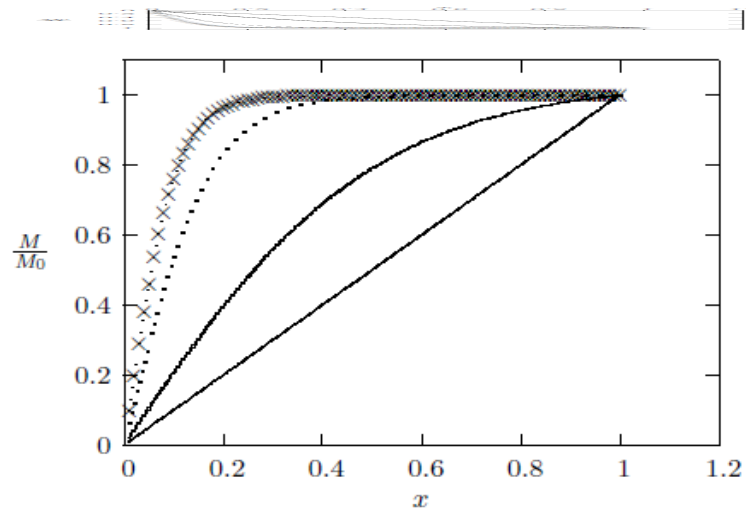
- Spontaneous magnetization $M_s(T) = M(T, H = 0)$



- Domain wall energy
- $E = \frac{A}{Na} + K N a$
- Using a minimization approach important magnetic properties for selected bulk materials are calculated.

	M_0 in $\frac{MA}{m}$	T_C in K	δ in nm	γ in $\frac{mJ}{m^2}$	H_C in $\frac{kA}{m}$
NiFe	0.84	800	258.2	0.077	0.28
Fe	1.71	1043	12.65	1.265	4.65
Co	1.44	1393	4.344	4.604	58.6

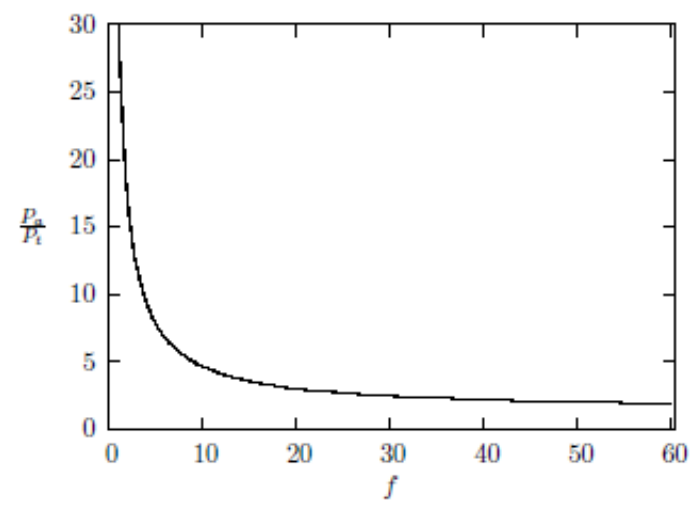
Due to the anisotropy effect the magnetization curves $M(H)$ depend on the angle α of H with respect to the easy axis of magnetization.



- A quantitative description of the Barkhausen effect (Bertotti model) is used to describe eddy current losses in ferromagnetic metals. Plotted is the anomaly factor F as a function of frequency. The asymptotic value is in agreement with the 2nd law of thermodynamics.
Evaluation of the penetration depth

- $$\delta = \sqrt{\frac{2}{\omega \sigma \mu_r \mu_0}}$$

- reveals that the Barkhausen signal can only be used to characterize the microstructure close to the surface of the magnetic material.



Conclusions

- The article presents a theoretical investigation on magnetic Barkhausen noise and dynamic domain wall motion.
- From the Heisenberg Hamiltonian important magnetic properties are calculated in qualitative agreement with other authors.
- Eddy current losses in ferromagnetic metals are successfully modeled.
- Magnetoacoustic emission is useful for detecting microstructural features. Electromagnetic techniques in NDE have a special role to play here.