Microscale magnetization dynamics in soft ferromagnetic materials.

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The macroscale magnetization dynamics in conventional ferromagnetic materials has not been fully understood so far. A promising direction of research that should contribute in elucidation of this classical problem is investigation of the magnetization dynamics on a microscale level by measuring Barkhausen noise (BN) and magneto-acoustic emission (MAE). These micro-magnetic signals originate from irreversible magnetic and acoustic pulses generated by moving domain walls.

We studied the microscale magnetization dynamics for typical soft ferromagnetic materials: a thin ribbon and electrical steels. BN and MAE were measured simultaneously with the classical hysteresis loops under the controllable magnetization conditions: sinusoidal/triangular waveforms of magnetic polarization/induction *J(t)/B(t)* or field *H(t)*. Magnetizing frequency was varied in a wide range 0.5-500 Hz fixing the magnetization amplitude on a near-saturation level.

Main results are presented in Fig. 1. Intensities of the micro-magnetic signals rise with magnetizing frequency as a square root function, which is supposed to describe a general dynamic trend [1]. Combining this finding with our earlier observations that the micro-magnetic signals are governed by the field rate of change *dH/dt*, the dynamic normalization of the rms envelopes to √*dH/dt* is proposed. After this normalization, the envelopes become of the same level, which is typical for the differential permeability curves obtained by a direct dH/dt normalization of the low-frequency induction signal.

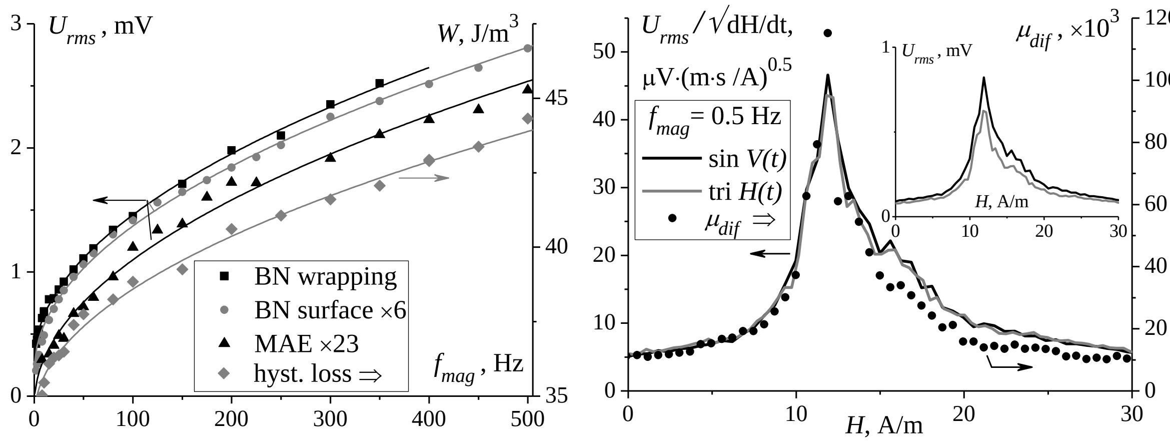

Figure 1. (Left figure) Intensities of the micro-magnetic signals (left scale) and the hysteresis losses (right scale) as functions of the magnetizing frequency. Data are obtained for a soft nanocrystalline ribbon at the sinusoidal polarization *J(t)* and are fitted by a square root functions. (Right figure) Two BN envelopes normalized to a square root of the corresponding field rates of change. The envelopes are measured by the sample-wrapping coil at the sinusoidal magnetizing voltage *V(t)* and the triangular field waveform *H(t)*. Inset shows the corresponding raw envelopes. Differential permeability curve for the sinusoidal *V(t)* is shown by dots and is referred to the right scale of the main figure.

[1] A. Stupakov, O. Perevertov, M. Landa, Dynamic behaviour of magneto-acoustic emission in a grain-oriented steel, J. Magn. Magn. Mater. **426** (2017) 685 – 690.