Magnetic characterization under PWM and PWM-like excitations

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Pulse-Width-Modulation (PWM)-like voltages are typical operating conditions for magnetic cores, but introduce additional complexity in the characterization and loss prediction due to the presence of high-order harmonics, minor hysteresis loops, and fast dynamics. Experimental characterizations under controlled induced voltage are undertaken to investigate the dependence of the magnetic loss on the PWM specific parameters, and to identify the most important quantities to measure for an accurate representation of the material behaviour in such conditions.

Keywords: PWM; Magnetic characterization; Magnetic loss; Electrical Steels.

1. Introduction

Inverter-driven electrical machines and power electronics magnetic cores are both typically supplied by pulse-width modulated excitation. Such supply exhibits a high-harmonic content that creates highly dynamic minor hysteresis loops at different positions along the major loop (see Figure 1). Consequently, the magnetic properties of the cores significantly differ from those measured under standard (sinusoidal) test conditions [1]. However, the reproduction of such PWM-like waveforms introduces additional difficulties in the characterization (including amplifier slew rate requirements, resonances with parasitic capacitances, and the combination of wide and small oscillations).

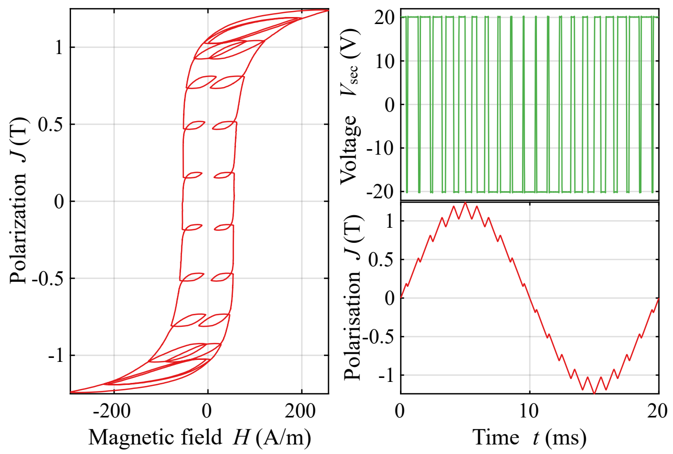

Figure 1: Experimental waveforms corresponding to a controlled PWM-like induced voltage, with $J_p = 1.25$ T, $f = 50$ Hz, $m_f = 21$ and $m_a = 0.8$ (Fe-(3wt%)Si strips, Epstein frame).

Pulse-width modulated excitations are defined by their peak polarization J_p, the fundamental frequency f, the amplitude modulation index m_a, and the ratio of switching frequency over fundamental frequency m_f. Each of these parameters significantly affects the loss in the core [2].

2. Results and discussion

Characterizations of Non-Oriented FeSi laminations are conducted for a subset of conditions, both using an Epstein frame (for low frequencies) and on cut and annealed toroids (higher frequencies). Such characterizations are illustrated in Figure 2 for given values of f and m_f while varying J_p and m_a, showing a consequent decrease of the loss, similar for all three J_p values, that can be related to lower polarization rate-of-change (i.e., a lower value of the induced voltage) and lower ripple (smaller minor loops). Varying the values of the four parameters (J_p, f, m_a, m_f) gives a more comprehensive representation of their impact and interactions.

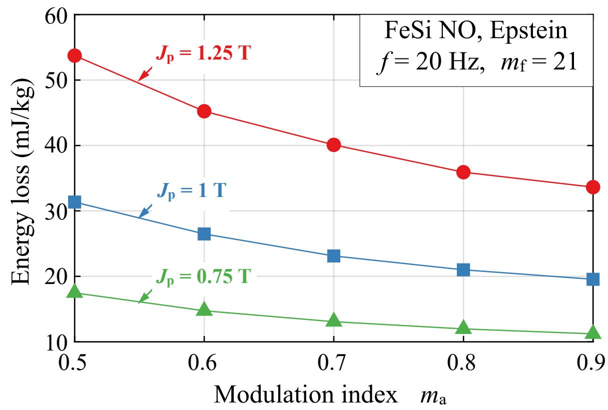

Figure 2: Measured energy loss under PWM conditions, for given values of the peak polarization J_p, as a function of the modulation index m_a ($f = 50$ Hz, $m_f = 21$, Fe-(3wt%)Si strips, Epstein frame).

To put in evidence the parameters that affect the losses with PWM supply, simplified test conditions are considered, such as supplying the system with a truncated PWM spectrum, or separating the experiments related to the minor and major loops. In both cases, the loss measurements related to both the full PWM supply and the simplified one (reduced spectrum / separated measurements) are compared and commented.

References

[1] E. Barbisio *et al.*, IEEE Trans. Magn. **40** (2004), 1810-1819.
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