In-line fluxmetric thickness measurement setup for grain-oriented steels

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A fluxmetric-based system is presented for measuring the thickness of grain-oriented steels. The method relies on magnetic flux measurement under saturation, using a low-noise analog integrator for accurate signal acquisition. Experimental validation on different grain-oriented Fe-Si laminations shows low relative errors and good measurement repeatability.

Keywords: fluxmetric measurement; grain-oriented steel; non-destructive thickness gauge

1. Introduction

The accurate, non-destructive measurement of the thickness of grain-oriented (GO) electrical steel sheets is essential for ensuring quality control in transformer core manufacturing. This work presents the development and experimental validation of an in-line thickness measurement system based on a fluxmetric method under saturation conditions. The proposed method is specifically designed to operate non-invasively on GO steel sheets during production or laboratory inspection stages. The measuring principle relies on exciting the sample up to magnetic saturation and estimating its cross-sectional area from the peak value of the magnetic flux [1]. Assuming prior knowledge of the saturation polarization J_{sat}, dependent on the physical properties of the material, and the sample width b, the unknown thickness d can be determined as

$$d = \frac{\Phi_{\max}}{J_{\mathrm{sat}}\, b}\, k,$$

where $\boldsymbol{\Phi}_{\max}$ is the peak value of the flux of the magnetic polarization J, and k is a calibration factor.

The measurement setup includes a non-standard Single Sheet Tester (SST), an autotransformer-based excitation source, and a signal acquisition and processing stage, as represented in Figure 1.

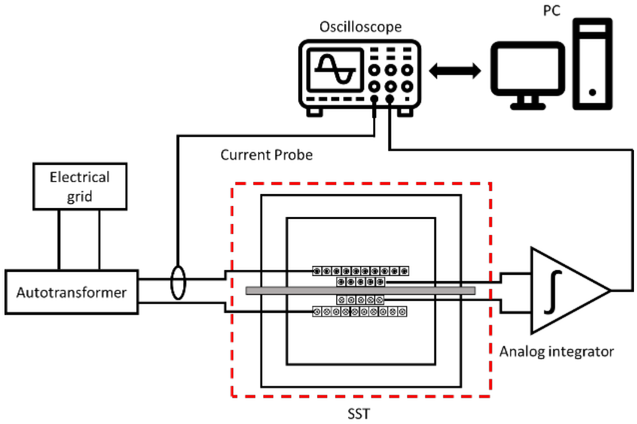

Figure 1: Schematic of the fluxmetric measurement setup.

Due to the highly distorted nature of the induced voltage waveform under magnetic saturation, numerical integration required to compute the magnetic flux may lead to significant errors because the voltage signal exhibits a wide dynamic range and remains small but non-negligible for most of the period, making it particularly sensitive to quantization and drift. An analog integration approach was then adopted to address these issues, based on a precision, low-noise circuit composed of a pre-amplification stage and an operational amplifier integrator. This solution provides a stable, calibrated output signal directly proportional to the magnetic flux linked to the sample. The signals are acquired using a Lecroy MDA 805A digital oscilloscope with 12-bit vertical resolution.

2. Results

A comprehensive experimental campaign was conducted on different GO Fe-Si laminations. Three samples with varying thicknesses were selected from different coil locations for each material. The actual thickness of each sample was independently determined using a high-precision balance, serving as a gravimetric reference. Results are reported in Figure 2. These results confirm the validity and accuracy of the proposed method, which proves suitable for high-precision, non-destructive thickness monitoring of grain-oriented steels in both industrial and laboratory environments.

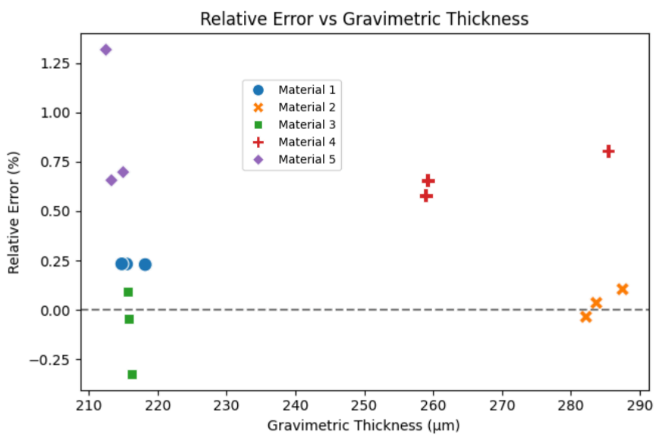

Figure 2: Relative error between fluxmetric and gravimetric thickness measurements as a function of the gravimetric thickness.

References

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