# On the connection between remanence and core noise in transformers

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This study investigates the connection between remanence and core noise in transformers, emphasizing the impact of nonlinear magnetic properties in laser-scribed Grain Oriented Electrical Steel (GOES). Through comprehensive lab tests and prototype transformer analysis, it was found that reduced remanence in GOES correlates with increased no-load sound levels and higher harmonic content. The findings highlight that increased nonlinear behaviour in magnetostriction, characterized by shifts in the point of reversal from negative to positive strain at lower induction levels, significantly affects core noise.

Keywords: remanence; hysteresis; sound; noise; magnetostriction

## 1. Introduction

The demand for lower no-load losses in transformers is rising due to the need for higher energy efficiency and reduced costs. Grain Oriented Electrical Steel (GOES) is crucial for this, optimized over the years to minimize iron losses through methods like laser scribing. However, recent observations show changes in the magnetic properties of some laser scribed GOES grades, specifically reduced remanence.

Lab tests and prototype transformers revealed that low remanence correlates with higher no-load sound levels and increased high-frequency content in transformers using affected materials.

# 2. Results and discussion

The impact of domain refined GOES with reduced remanence on no-load sound was examined through a twostage experiment. It involved producing and testing several prototype transformers and cores with different designs after thorough lab studies on sample material. A traceable connection between magnetic characteristics and no-load sound was established using the same batch of GOES for both lab testing and prototype production.

All GOES was domain refined by laser scribing and came from three suppliers, with lamination thicknesses ranging from 0.18mm to 0.27mm. Reduced remanence was noted for all batches. Reference transformers were produced using GOES without reduced remanence for comparative analysis. Examples of hysteresis curves can be seen in Figure 1.

Measurements indicate that the total sound pressure level of the prototype transformer units utilizing material with reduced remanence is up to 14 dB(A) higher compared to the reference units. The effect is most severe for low thickness material but less pronounced for cores produced with thicker lamination. Moreover, the difference in total sound pressure level comes from increased harmonic content in the sound spectrum, and not necessarily due to an increased amplitude of the fundamental.

Single Sheet Tester (SST) and magnetostriction measurements indicate increased harmonic content in the strain under sinusoidal flux. The corresponding magnetostriction butterfly curves reveal that this is due to increased nonlinear behaviour, shifting the point of reversal from negative to



Figure 1. Examples of hysteresis curves for 0.18mm thickness material exhibiting reduced remanence (red) and 0.20mm reference material (black).

positive strain to lower induction levels. Potential root causes of the altered magnetic properties of laser-scribed material from some suppliers include the use of an excessively high laser power [1]. The resulting high residual stress potentially induces a relatively large volume of transverse domains, resulting in an earlier onset of domain rotation [2]. This corresponds well with the reduced remanence seen in the hysteresis curves and would also explain the shifted nonlinearity in the butterfly loops.

Even small increases of magnetostriction harmonics can have profound impact on core noise and vibrations. High order magnetostriction harmonic forces are likely to interact with the cores' eigenmodes. This can occur even if the corresponding eigenfrequency is relatively far from the nearest line-frequency multiple, depending on the mechanical damping properties of the core.

### References

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