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► **To cite this version:**

Guillaume Parent, Rémi Penin, J. Lecointe, Jean-François Brudny, Thierry Belgrand. Influence of the electrical steel grade on the magnetic flux distribution in transformer core corners. The Sixteenth Biennial IEEE Conference on Electromagnetic Field Computation (CEFC 2014), May 2014, Annecy, France. pp.1. hal-04114217

**HAL Id: hal-04114217**

**<https://hal.science/hal-04114217>**

Submitted on 26 Oct 2023

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# Influence of the electrical steel grade on the magnetic flux distribution in transformer core corners

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**Abstract**—This paper deals with the study of the local distribution of the magnetic flux inside transformer cores. The influence of the magnetic steel grade on the local saturations occurring in the laminations situated in the transformer parts are studied with both an experimental device and a Finite Element analysis. It is shown that this steel grade is of high influence on that phenomenon, and so on both the core losses and the acoustic noise generated.

**Index Terms**—Finite element methods (FEMs), grain oriented electrical steel, magnetic cores, transformers.

## I. INTRODUCTION

This phenomenon is complex and due to two main sources : Maxwell's forces and magnetostriction. Hence, in order to reduce it, it is critical to understand the magnetic flux distribution inside transformer cores, specially in the corners [1]. Indeed, since the core is made of Grain Oriented (GO) steel sheets, in the corner area, the magnetic flux has to pass from a lamination to another one by crossing the air gaps between them. That creates both Maxwell's forces and high local magnetic saturations [2].

In this paper, the influence of the magnetic steel grade on the magnetic flux distribution inside the corners is studied. In particular, the paper highlights, with both a Finite Element (FE) analysis and an experimental device, that in a corner:

- the critical  $B_C$  flux density [2] greatly depends on the magnetic steel grade
- in a lamination, the saturation level along the Rolling Direction (RD) and the Transverse Direction (TD) can be of the same order

## II. STUDIED STRUCTURE

The studied structure consists in a GO laminations stack in frame shape. The stack is composed of three sheets the RD of which are shifted with an angle of  $90^\circ$  (Fig. 1), excited by a winding regularly laid out and supplied by a sinusoidal current. That way, this structure presents the same magnetic permeability configuration than the one encountered in a Multiple Step Lap (MSL) corner joint with a N number of steps equal to 2.

## III. FINITE ELEMENT ANALYSIS AND RESULTS

The FE analysis has been performed using three different grade of sheets: CGO 0.30 mm, HGO 0.30 mm and HGO 0.23 mm. As an example, Fig. 1 shows the magnetic flux density distribution in two contiguous laminations in the case of HGO 0.30mm. The distribution is as expected, *ie* the

magnetic flux follows the RD as long as it can and then passes from a lamination to another one in the corner area.

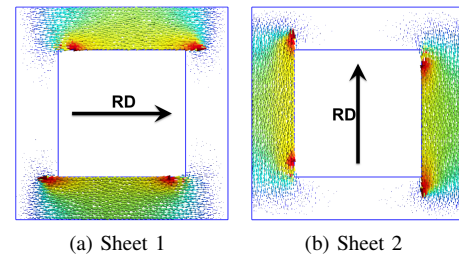


Fig. 1: Magnetic flux distribution in the structure

Nevertheless, in the corner area, Fig. 2 shows that:

- depending on the global value of the magnetic flux density in the structure, the flux density distribution between the RD ( $B_{RD}$ ) and the TD ( $B_{TD}$ ) depends on  $B_C$ . Indeed, before  $B_C$  is reached, the whole magnetic flux takes place in the RD. But as soon as this value is reached, the magnetic flux is spread between both directions.
- the value of  $B_C$  clearly depends on the steel grade

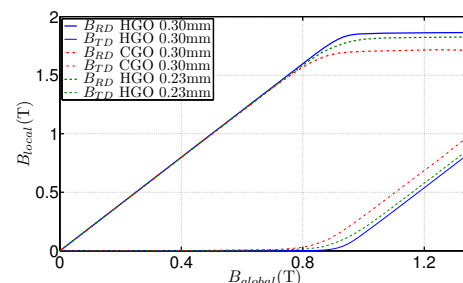


Fig. 2:  $B_{RD}$  and  $B_{TD}$  inside a lamination in a corner

Hence, the iron losses and the acoustic noise greatly depend on the steel grade, as shown by both the experimental and the FE results that will be presented in the final paper.

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