Effects of pulsed laser ablation with non-conventional patterns on rotational magnetic properties of GO electrical steels

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Classical laser treatments (irradiation, scribing) are commonly used to improve magnetic properties of Grain-Oriented Electrical Steels (GOES) along their Rolling Direction (RD). Besides them, a new process called ablation performed with UltraShort Pulsed Lasers (USPL) has recently been developed. It can boost GOES's magnetic properties along the RD, along the Transverse Direction (TD) and along other directions providing laser pattern adjustments to optimize performances in each case. However, these enhancements only concern 1-directional alternating fields. In this work, the impacts of an ablation process on GOES's magnetic properties under rotational excitation are investigated. A pattern adapted for RD excitation, several patterns adapted for TD / close to TD excitations and a combination of both types of patterns are used and compared. Experimental results show that the ablation process can also reduce GOES rotational losses with interesting reduction rates. The necessity of adjusting the laser pattern to excitation conditions is confirmed, especially when the field rotates.

Keywords: Grain-Oriented Electrical Steels, 2D Vector Magnetic Properties, Rotational Losses, Pulsed Laser Treatment

1. Introduction

Due to worsening properties when the excitation direction moves away from the RD, the use of GOES inside rotating electrical machines is very limited and performances of transformers are reduced (in the corners or T-joints). To change this, one can modify the properties of GOES sheets, which is feasible using surface laser treatments. If performances along the RD being enhanced thanks to laser treatments is no longer to be proved, studies of the effects of laser treatments under excitation conditions different than along the RD remain very limited [1-2]. Recently, a new laser process called ablation was tested under several unidirectional excitation conditions [2]. However, the study remains incomplete because no rotational excitation conditions were tested. Hence, to push the study further and following encouraging results obtained after an irradiation laser treatment with different patterns under rotating field [1], investigation on the effects of ablation laser process applied in the form of different patterns must be carried out under rotational excitation conditions.

2. Results and discussion

To study the effects of ablation applied with different patterns on magnetic properties of GOES under rotational excitation conditions, 60 mm square samples made of an industrial grade are characterized using a Rotational Single Sheet Tester (RSST) before and after laser treatment (ablation process) on the same sample. The RSST uses a pocket solution for B/H measurements. It allows to avoid drilling samples which could distort the study of the laser impacts due to induced constraints. At each step (before / after laser treatment) and for each circular polarization / frequency configuration, rotational power loss measurements are performed twice (ClockWise and Counter-ClockWise) and averaged. Figure 1 shows rotational power loss variations after laser treatment at 50 Hz (same laser parameters, 3 patterns). Patterns were selected based primarily on results presented in [2]: Pattern 1 (resp. Pattern 2) is adapted for improving properties along the RD (resp. TD), and Pattern 3 is a combination of Pattern 2 and 3. Results show that all patterns allow rotational power loss reductions. Multiple mechanisms are involved in rotational field, but the ones associated to the TD induce much more losses which it is more profitable to reduce thanks to Pattern 2. Pattern 3 combining the other 2 patterns gives best reduction rates up to 1 T, then increases significatively the losses. Physical interpretations will be further discussed in the extended communication. Other laser patterns will also be presented. B – H loops and magnetic structure observations may also be considered to complete the power loss measurements analysis. Present study reasserts the necessity of adapting the laser pattern to excitation conditions and questions the possibility of tailor-made GOES magnetic circuit for transformers and rotating electrical machines.

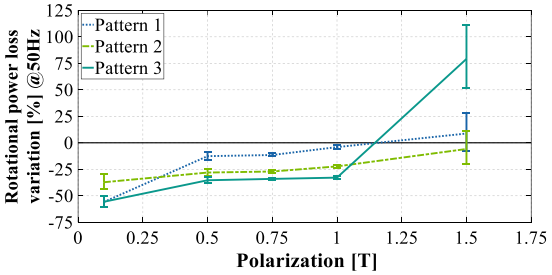

Figure 1: Rotational power loss variations [%] at 50 Hz after ablation laser treatment in the form of different patterns (including repeatability error bars; systematic bias errors are neglected due to before / after relative comparison on the same sample).

References

[1] T. Kajiwara and M. Enokizono, IEEE Trans. Magn., **50** (2014)
[2] P. Dupont, *et al.*, JMMM, **592** (2024), 171746

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