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Surface ablation of the GO FeSi Electrical Single Sheet: Impact on the Static/ Dynamic Magneto-Mechanical Behavior and Optimization

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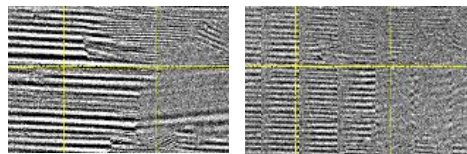
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ABLATION TECHNIQUE

Surface ablation technology: the ultra-short pulse laser, material and coating removal by sublimation with a laser tracing line without significant thermal effect [1].

Impact on the structure: energy levels modification: magnetoelastic, magnetocrystalline anisotropy, magnetic exchange and magnetostatic demagnetizing energy. Reduction of the fraction volume of disoriented domains, Domains refinement and Demagnetization effect increase.

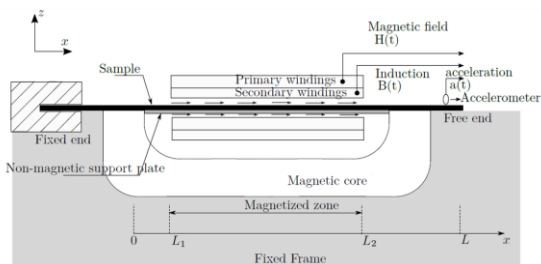
Impact on the macroscopic behavior: iron loss reduction [2], permeability change & magnetostriction reduction [3].



Before ablation

After ablation

MEASUREMENTS



- Grain Oriented Electrical Steel 280mm x 30mm plates.
- Magnetic signals measured using a Single Sheet Tester.
- Mechanical signal (acceleration) measurement using piezoelectric accelerometer on a fixed-free plate [4].
- Synchronous measurements.
- Collected signals: induction, magnetic field and acceleration
- Collected data: iron losses, permeability and effective velocity (V_{rms})

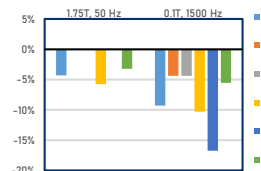
PARAMETRIC STUDY

- Different laser configurations conducted by several optimized laser parameters.
- Each configuration is characterized by a different cumulative energy density and a power density.
- Results are compared before and after ablation.

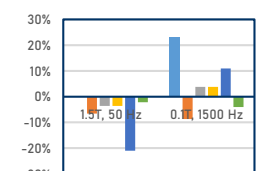
Conf.	Nb pass	Power P/Pref	Speed V/Vref	Line spacing D/Dref
1	2	1	1	1
2	1	1	1	1
3	1	1	1	0.8
4	1	1	1	0.6
5	2	1	1.3	0.6
6	1	0.8	1.1	0.6

RESULTS

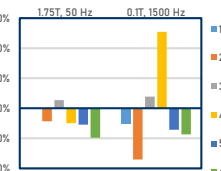
- Comparison of the iron losses variation with the magnetostriction variation
- Iron losses reduced up to 15% at high frequency: due to the domains refinement
- Permeability decrease at high induction: due to the increase of the demagnetizing energy.
- Permeability increase at low induction/high frequency: decrease of the fraction volume of disoriented domains.
- Noise reduction (RMS velocity) up to 50%: decrease of the fraction volume of disoriented domains with means decrease of magnetostriction.



Iron losses Variation

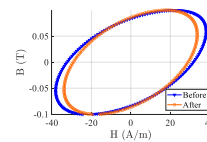


Permeability Variation

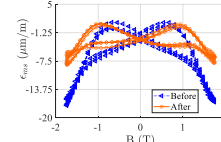


RMS Velocity Variation

- Best Configuration for 50 Hz frequency/high induction: 6
- 1 laser pass and small lines spacing.
- Best Configuration for high frequency/low induction: 1
- 2 laser passes and big lines spacing.



Hysteresis at 0.1 T 1500 Hz (Conf.1)



Butterfly loop at 50 Hz (Conf. 6)

REFERENCES

- [1] M. Nesser et al., Correlation between laser energetic parameters and magnetic properties of GO laminations under surface treatments with long and short pulsed lasers, *J. Magn. Magn. Mater.*, 503(June 2020), 166696.
- [2] M. Enokizono T. Kajiwara. Effect of Laser Stress on Vector Magnetic Properties of Electrical Steel Sheets.(50(4)):2002404, 2014.
- [3] A. Allwardt et al. Improved Transformer Noise Behavior by Optimized Laser Domain Refinement at ThyssenKrupp Electrical Steel. (48(4)):1453-1456, 2012.
- [4] E. Salloum et al., Identification of Magnetic Induced Strain of Electrical Steels Using Non-Destructive Acceleration Measurement and Inverse Vibration Modeling., *J. Sound Vib.*, 492(February 2020), 115806.