Experimental Characterization of Laminated Ferromagnetic Materials for Calculation of PWM Induced Iron Losses

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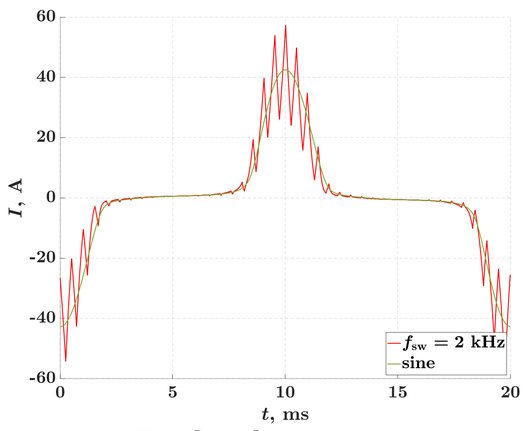
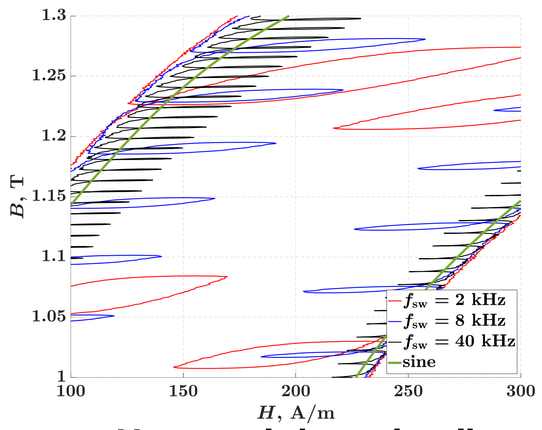
1. Introduction

With the transition from sinusoidal AC voltage supply to PWM voltage supply, losses in the magnetic circuit increase. This distortion causes relatively small remagnetization cycles to form during the main cycle, increasing the total iron losses.

Sinusoidal vs PWM



Excitation current



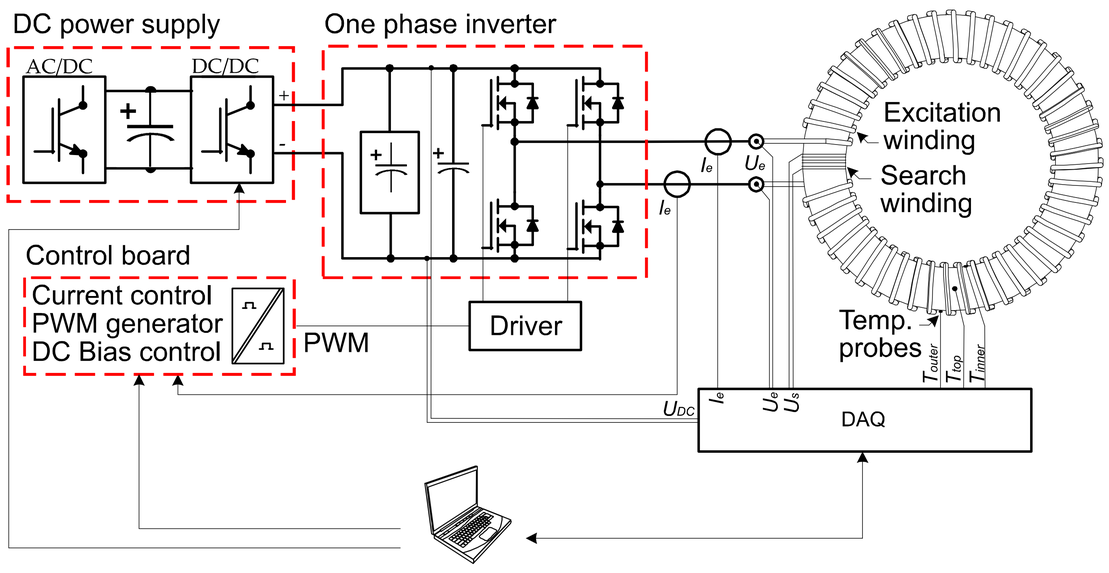
Hysteresis loop detail

2. Problem Description

The research objective is to determine the influence of PWM and inverter parameters on iron losses and to establish the methodology for measurement and data processing required to produce loss data maps that can be used to improve the accuracy of total loss estimate for an electrical machine.

3. Methodology

A novel measurement setup for estimating PWM-induced losses was proposed and built. A wide operating range of excitation frequencies and varying DC bias field is achieved. Several ferromagnetic laminated ring-core specimens were used in experiments for the collection of the material loss data.



Measurement setup block shematics

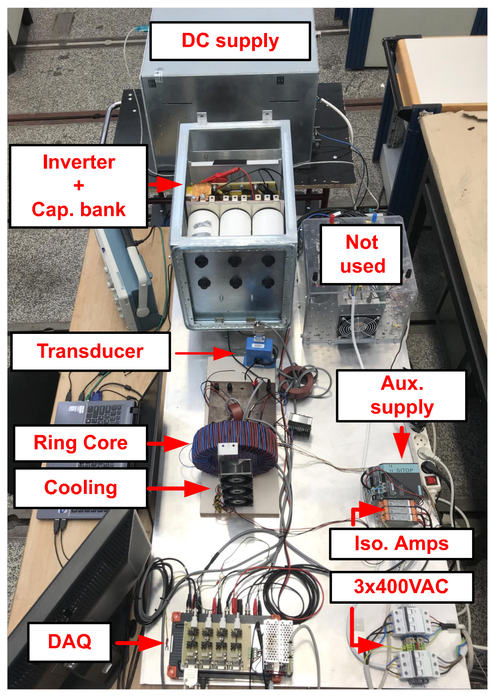


Photo of measurement setup

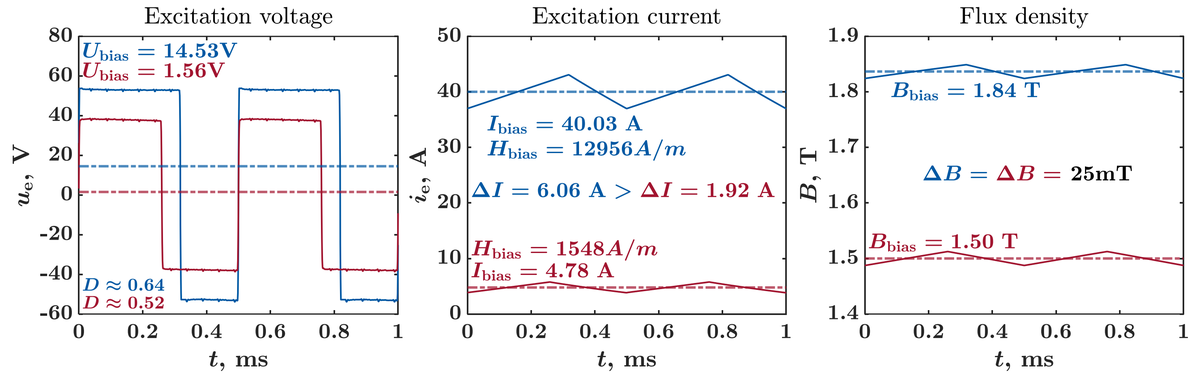
The key features:

- Single excitation winding used to achieve both DC bias and flux ripple
- The use of an over-dimensioned power-stage as a stiff voltage source

Basic setup parameters

Part	Specification
DC supply	500V, 15kW, 90A
Inverter	SiC, 300A, 40kHz
Measuring equipment	1MHz DAQ, 200-700A zero-flux current transducer

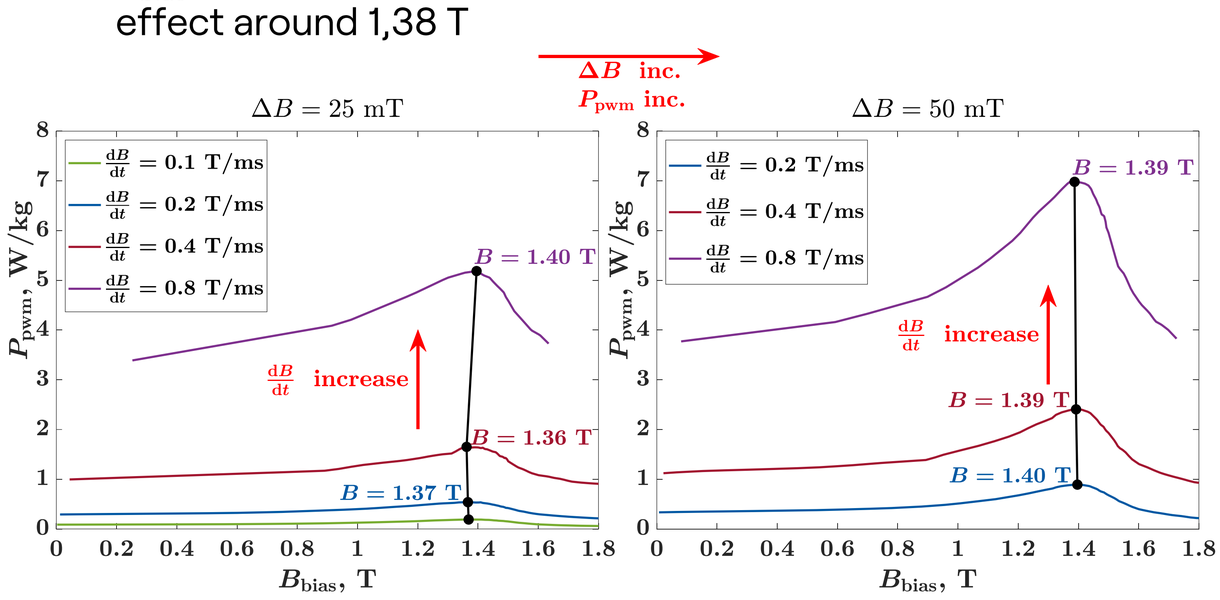
The DC bias experiment provides iron loss data dependent of the ΔB, $\mathrm{d}B/\mathrm{d}t$ and B_{bias} value.



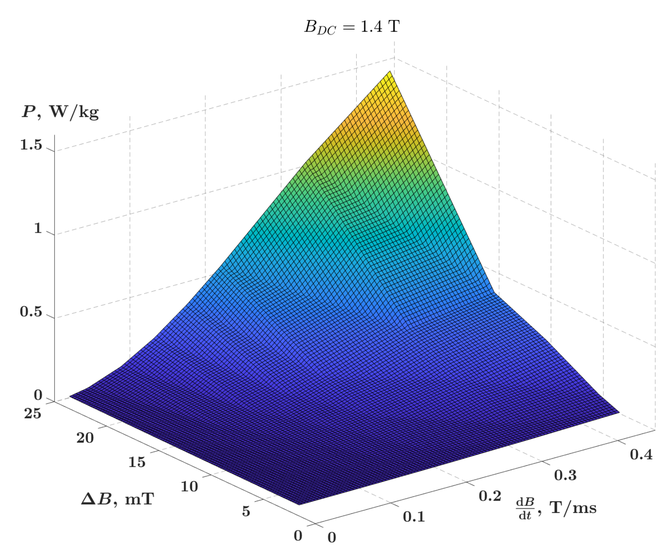
Typical waveforms for DC bias measurements at f_{sw} = 2 kHz and $\mathrm{d}B/\mathrm{d}t$ = 0.1 T/ms

4. Results

- ΔB: linear effect on losses, slope is function of B_{bias}
- $\mathrm{d}B/\mathrm{d}t$: exponential effect on losses
- B_{bias}: hysteresis dependent relation on losses, maximum effect around 1,38 T



PWM loss contribution in correspondence to ΔB, $\mathrm{d}B/\mathrm{d}t$ and B_{bias} parameters



- Results are organized in the form of 3D loss maps
- Data is used as input to FEA simulations
- More accurate overall estimate of sinusoidal and PWM iron losses
- Laser cutting affect and core non-uniformity is taken into the account

5. Conclusion

- A novel measurement setup is proposed and built to analyze the impact of the PWM power supply on the total AC losses
- Combining 3D loss data maps and field solution results in PWM contribution to the iron losses
- Simple core geometry can be used for calculation of iron losses in complex geometry core (e.g. electric motors)

6. Project Acknowledgement

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