Investigating the Interlaboratory Reproducibility of Magnetic Flux Measurements of Toners

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Disclaimer

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Introduction

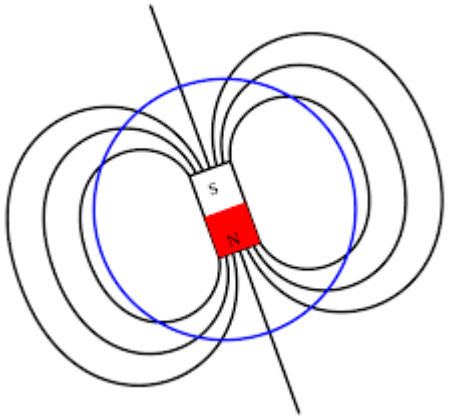
Utility of Magnetic Flux Measurements

- Toner printed documents are increasing in prevalence in FDE casework
  - Szafarska et al (2011) found up to 59% of a modern caseload consists of printed documents
- Current methods provide a limited ability to discriminate
  - Current guideline recommends ‘Complementary Analyses’
  - Costly instrumentation and reagents
  - Time consuming analysis and interpretation
  - Destructive

Utility of Magnetic Flux Measurements

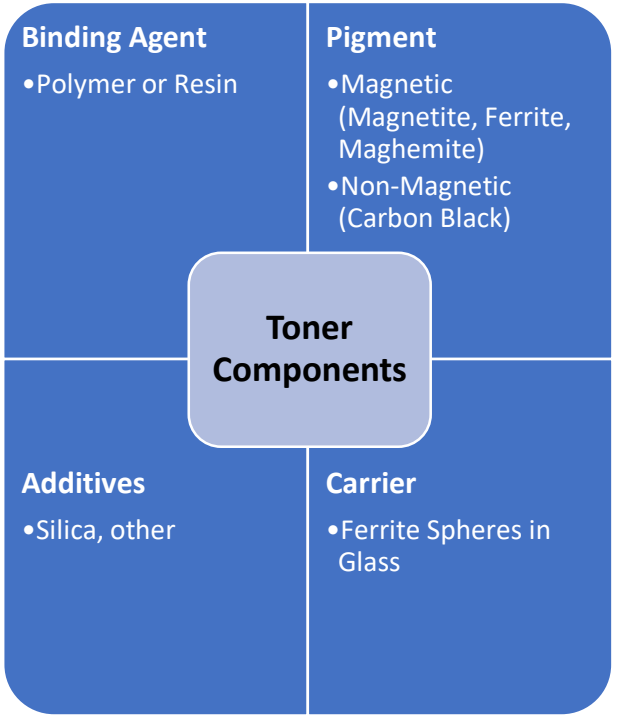
- Magnetism has been assessed as part of the standard forensic examination scheme for toners since 1987
  - Initially proposed by the FBI as a categorical classifier
  - Updates in sensor technology allowed for the quantitation of magnetic flux

- What is Magnetic Flux?



Utility of Magnetic Flux Measurements

- Magnetic compounds can be present in toner
  - Previously used for categorical classification
  - Application of quantitative measurements recently developed, but not widely investigated
- Toner binding agent variation is not independently enough for individualization of samples
  - Biedermann et al. study (2016) found only 4 resin groups as measured by ATR-FTIR for 61 different samples
  - Quantitative magnetic flux measurements aided in discrimination of samples from the same FTIR resin group



Utility of Magnetic Flux Measurements

- Previous Research:
  - Herlaar *et al*, 2015
    - Repeatability of measurements
    - 72 samples, 19 devices
  - Biedermann *et al*, 2016
    - Repeatability and reproducibility of measurements
    - Inter-Operator variability
    - 61 samples, 61 devices

Utility of Magnetic Flux Measurements

- Previous Research:
  - Mazzella and Li, 2018
    - Homogeneity of flux distribution
    - 17 samples, 6 devices and 3 cartridge types
  - Polston *et al*, 2018
    - Stability of magnetic flux fields over time
    - Relationship between toner area and flux
    - Variation in a representative population sample
    - 212 samples, 150 monocomponent toner

Summary of Previous Research

- Magnetic flux of toners:
  - Is stable over time
  - Measurements are repeatable
  - Measurements can be conducted without damaging the sample
  - Data normalization is possible
  - Population variation is great enough to provide the potential to discriminate sample origin
  - Distribution is consistently inhomogeneously distributed
  - Hysteresis effects and induction spatial effects contribute significantly to variance in magnetic flux measurements
    - Must be considered in sampling methodology

Current Research Questions

- Are magnetic flux measurements of toners reproducible?
  - Do variables such as the operator, the instrument used, the software version, or the laboratory setup affect reproducibility of measurements?

Materials and Methods

General Overview

- Regula© Magmouse 4197
  - Used for all magnetic flux measurements by all participants
  - Positive and negative QC samples were used to monitor for proper instrument function

- Multi-layered project:
  - Sample design and development
  - Method design
  - Instructions for participants
  - Recruitment and dissemination process
  - Analytical Process

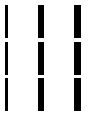
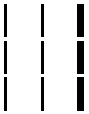
Sample Design

- Sample was designed to minimize extraneous variables
  - Controlled area, distribution of toner
  - Used grids of shapes of equal area
  - 0.71 mm^2 per block in each grid
  - 9 blocks per grid
  - Total of 6.39 mm^2 per grid
  - Participating labs only analyzed the square grids

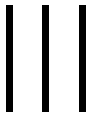
- Participating labs were provided with 3 toner samples and one negative QC

Sample Design

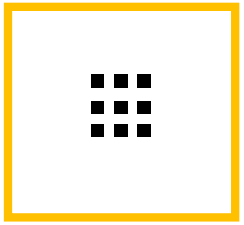


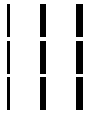
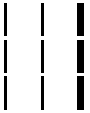





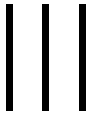



Sample Design








Analytical Method

- Analytical method information was provided for the participants
  - Information on how to set up the software upon initial installation
  - Conduct positive and negative QC checks
  - How to analyze the toner samples
    - 28 replicate measurements were collected for each sample
  - How to record data
  - Troubleshooting guide
  - Contact information for direct support

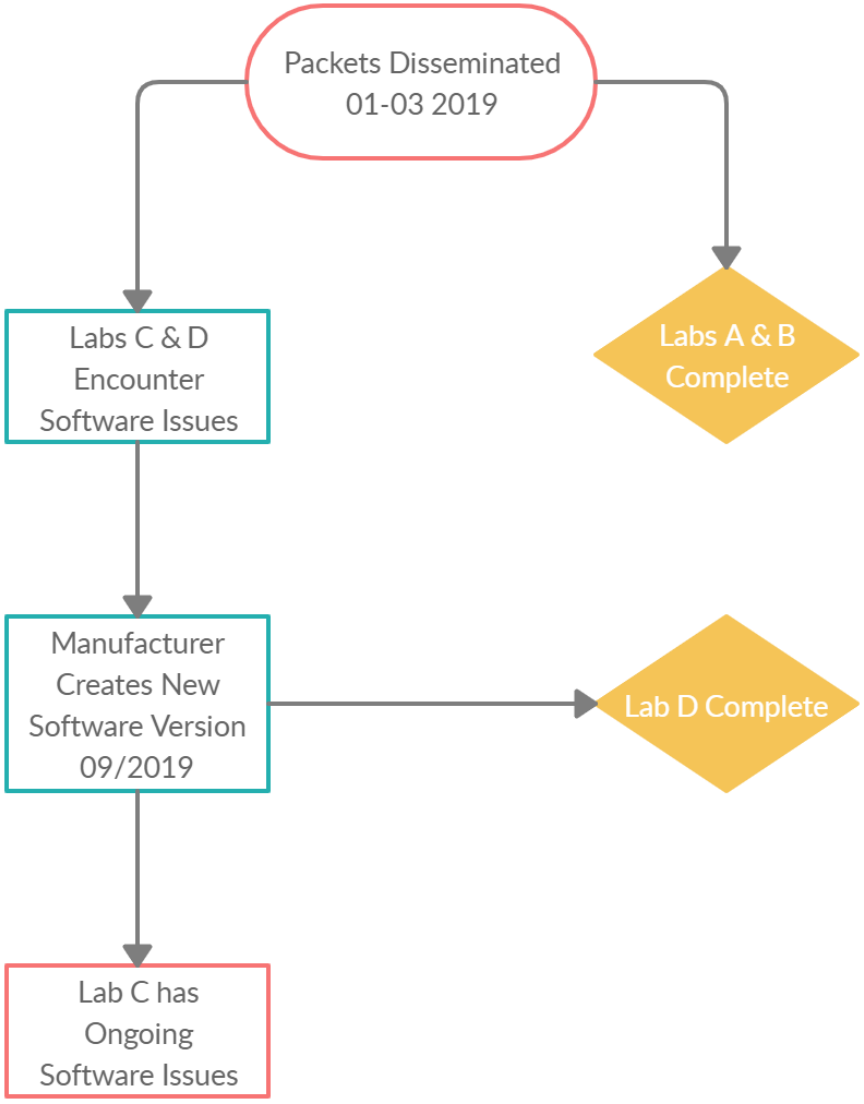
Dissemination

- Recruitment – through individual outreach and ENFSI posting
- Study packets were issued between January 2019 and March 2019
- 4 total labs participated
- Participating labs were instructed to first collect 28 replicate measurements of the indicated square grid on each sample using their own laboratory protocol before using the included methodology guide
  - Null – no participating laboratories had an official protocol in place

Laboratory Setups

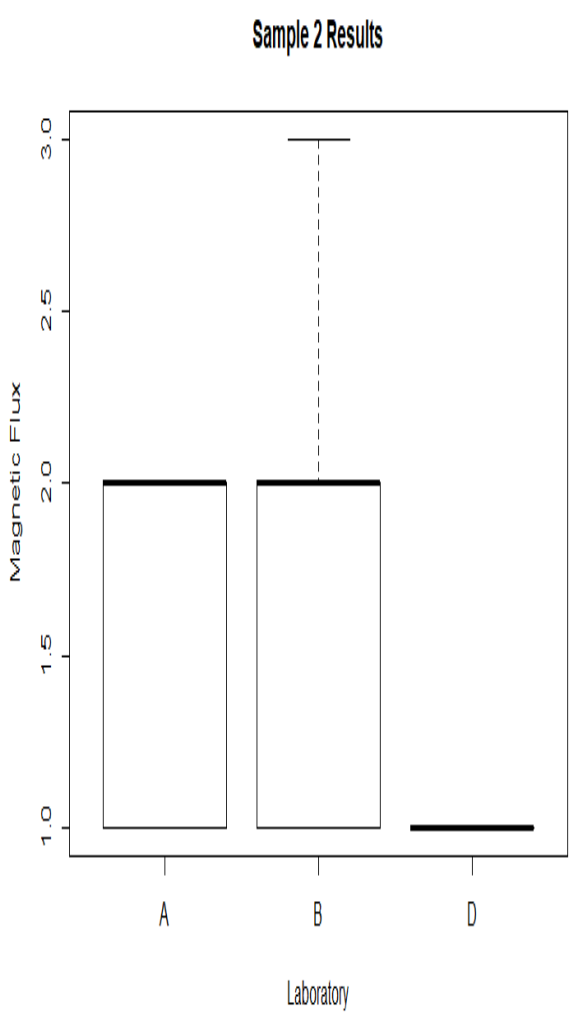
- Wide variation in instrumentation setup and capability between participating laboratories
- Software versions
  - V 0.78 – 0.92
  - V 0.92 – 0.97
- Driver Compatibility
- Instrument production order
  - Issue #9 through S/N 04172

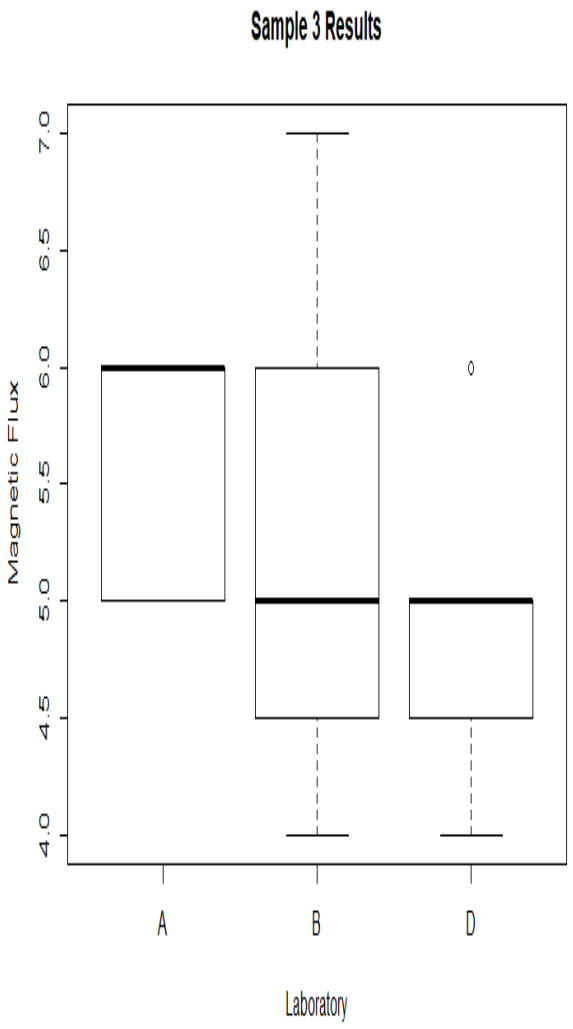
Analytical Process

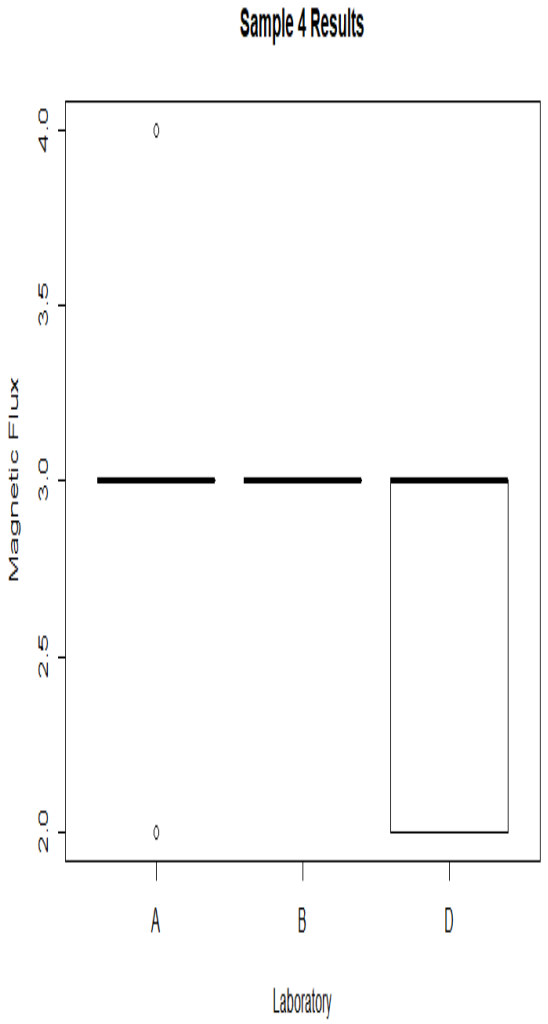


Results

Reproducibility







Reproducibility

- Overview:

Sample ID	Lab A	Lab B	Lab D
S002	1.7 ± 0.5	1.6 ± 0.6	1.0 ± 0.0
S003	5.6 ± 0.5	5.1 ± 0.9	4.9 ± 0.6
S004	3.1 ± 0.4	3.0 ± 0.0	2.6 ± 0.5

Reproducibility

- Used t-testing to check for significant differences between labs
  - Paired t-test for A to D comparison
  - Homoscedastic for others

- Results:

P-values	**S002**	**S003**	**S004**
Lab A vs D	>0.001	>0.001	>0.001
Lab A vs B	0.286	0.004	0.051
Lab B vs D	>0.001	0.064	>0.001

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Reproducibility

- Additionally, assessed the percent variance:

- 2016 Inter-Operator Study
  - Estimated 7-15%
  - 13% average
  - Operator only variable

- 2020 Inter-Laboratory Study
  - 1-19%
  - 7% average
  - Operator, Instrument, Software Version, Laboratory Setup

Conclusions

Conclusions

- Variables assessed do significantly impact reproducibility of measurements
  - Impact has improved since 2016 with improved method protocols, but still needs further refinement before meaningful comparisons can be performed between labs

- There is a strong need for a known reference material
  - No material exists to date – labs used manufacturer issued positive QC sample
  - Could assist in standardization of methods and results across labs and improve reproducibility of results

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Questions

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