Digital Walkthrough of the Validation of a Method for Measuring Magnetic Flux of Toner-Printed Documents

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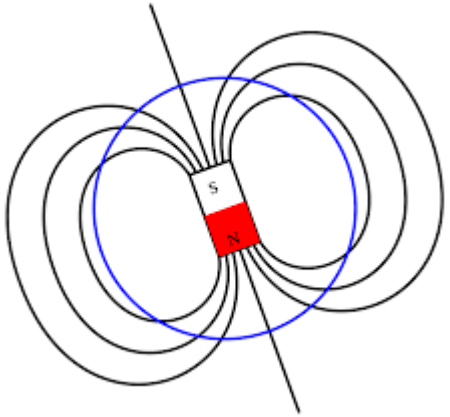
Disclaimer

- This research was not commercially sponsored, and the authors have no financial affiliations with any commercial product manufacturers

Introduction

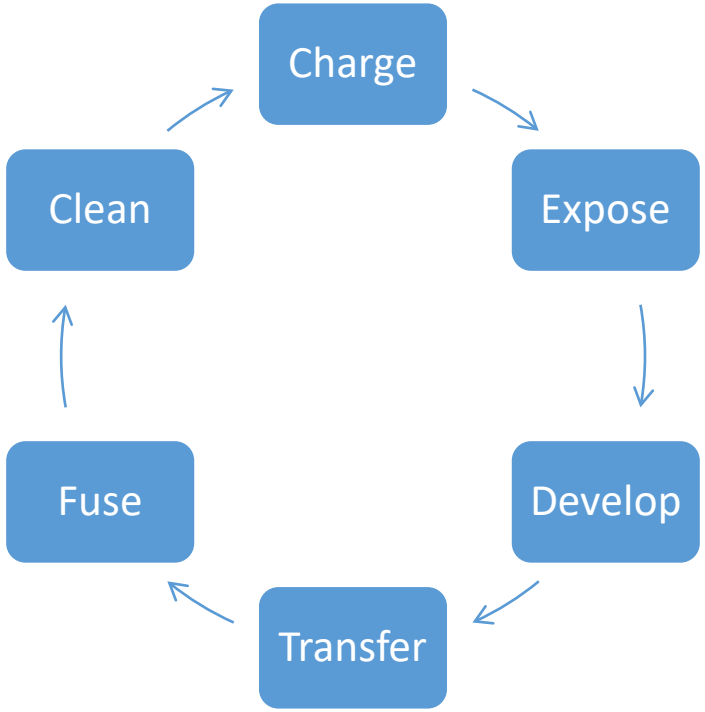
- Magnetic flux is a measure, in Webers, of the density of magnetic field lines passing through the surface of an object



- 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

Introduction

- **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
- **Mass device production and conserved use of the electrophotographic process complicate analysis**
  - Reduce sources of variation in samples
- **Current methods provide a limited ability to discriminate**
  - Current guideline recommends ‘Complementary Analyses’
  - Costly instrumentation and reagents
  - Time consuming analysis and interpretation
  - Destructive



Introduction

- 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
  - 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

Introduction

- This knowledge used to facilitate method development
  - Polston *et al*, 2019
    - 5 samples, 5 devices
    - Signal suppression and enhancement
    - Hysteresis effects
    - Biasing induction current spatial effects
  - Polston *et al*, 2020
    - Reproducibility of measurements
    - 4 labs
    - Different operators, instruments, laboratory setups

Introduction

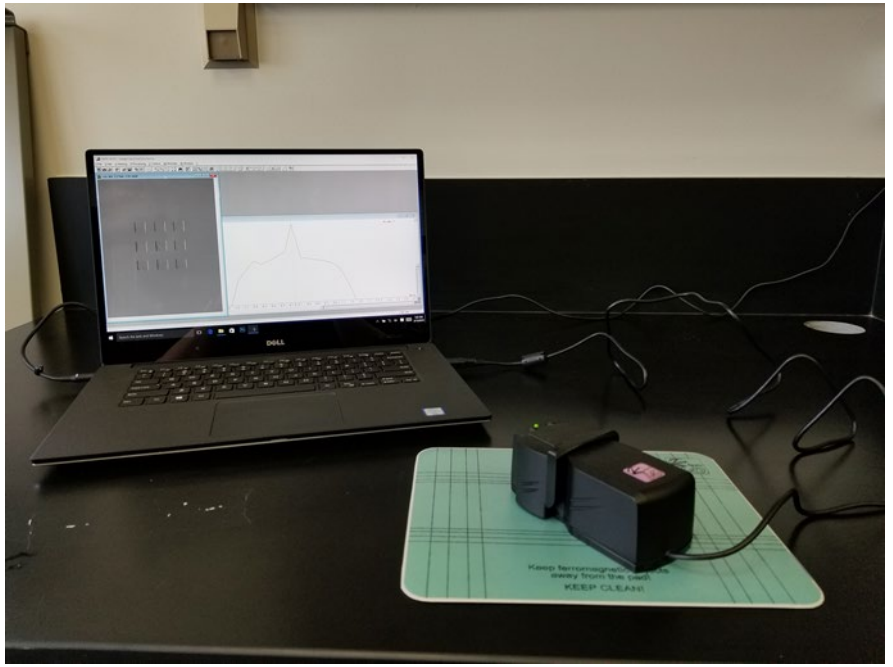
- In summary, magnetic flux of toners:
  - Is stable over time
  - Measurements are repeatable
  - Measurements can be conducted without damaging the sample
  - Data normalization is possible
  - Population variation is great enough to provide the potential to discriminate sample origin
  - Distribution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

Materials and Methods

- Multiple components:
  - Instrumentation
  - Validation protocol
  - Samples
  - Measurement methodology

Materials and Methods

- Instrumentation
  - Regula© Magmouse 4197
  - Used for all measurements
  - CADR Software – update version 0.98



Materials and Methods

- Validation Protocol:
  - No specific QD section guidelines, so adapted relevant sections from toxicology ASB validation guidelines

Validation Parameters	Criteria
LOD	*Previously assessed - Magnetic particles visible but no measured response
LOQ	*Previously assessed - Magnetic particles visible and measurement value 1 nWb
Precision	± 20%
Bias	± 20%
Suppression/Enhancement	*Previously assessed – hysteresis effects, biasing induction current effects
Sample Stability	*Previously assessed – stable long-term
Interferences	No impact on measurements
Matrix Effects	No impact on measurements

Materials and Methods

- Samples
  - QC samples
    - Negative and positive QC samples
  - Matrix samples
    - 5 different matrix sources
  - Interference study samples
    - 25 different materials
    - Pen inks, markers, inkjet inks
  - Population sample
    - 54 toner samples
    - 20 monocomponent toners

Materials and Methods

- Sample Information
  - Matrices
  - Interferents
  - Population

Manufacturer	Weight (g/sm)
Skilcraft	32
HP	32
Neenah	65
Georgia Pacific	32
Clairfontaine	90

Media	Number of Samples	Manufacturers	Colors	Models
Ballpoint Pens	8	6	3	7
Gel Pens	3	2	2	2
Rollerball Pens	2	2	1	2
Felt Tip Markers	4	2	3	2
Inkjet Inks	8	2	4	2

Manufacturer	Samples	Color	BW	Bicomponent	Mono
Brother	7	3	4	7	0
Canon	8	4	4	4	4
HP	27	12	15	12	15
Kyocera	1	0	1	0	1
OKI	2	0	2	2	0
Ricoh	3	1	2	3	0
Xerox	6	3	3	6	0

Materials and Methods

Measurement Methodology

- Bias and Precision
  - 2 sites on QC sample (low and high)
  - 5 replicates
  - 3 sessions
- Matrix Effects and Interferences
  - 3 sites on sample
  - 3 replicates
- Population
  - 1 site on sample
  - 5 replicates
  - ILS protocol

Results

Precision and Bias

	Toner QC data					
	Low QC			High QC		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Rep 1	30	33	27	57	63	57
Rep 2	31	34	28	58	64	59
Rep 3	31	28	29	62	58	67
Rep 4	31	32	29	62	57	61
Rep 5	32	28	29	63	61	60
p-w	2.3	9.1	3.1	4.5	5.0	6.2
p-b	6.9			4.9		
	27.71	59.33				
Bias	Low	High				
	8.7	2.1				

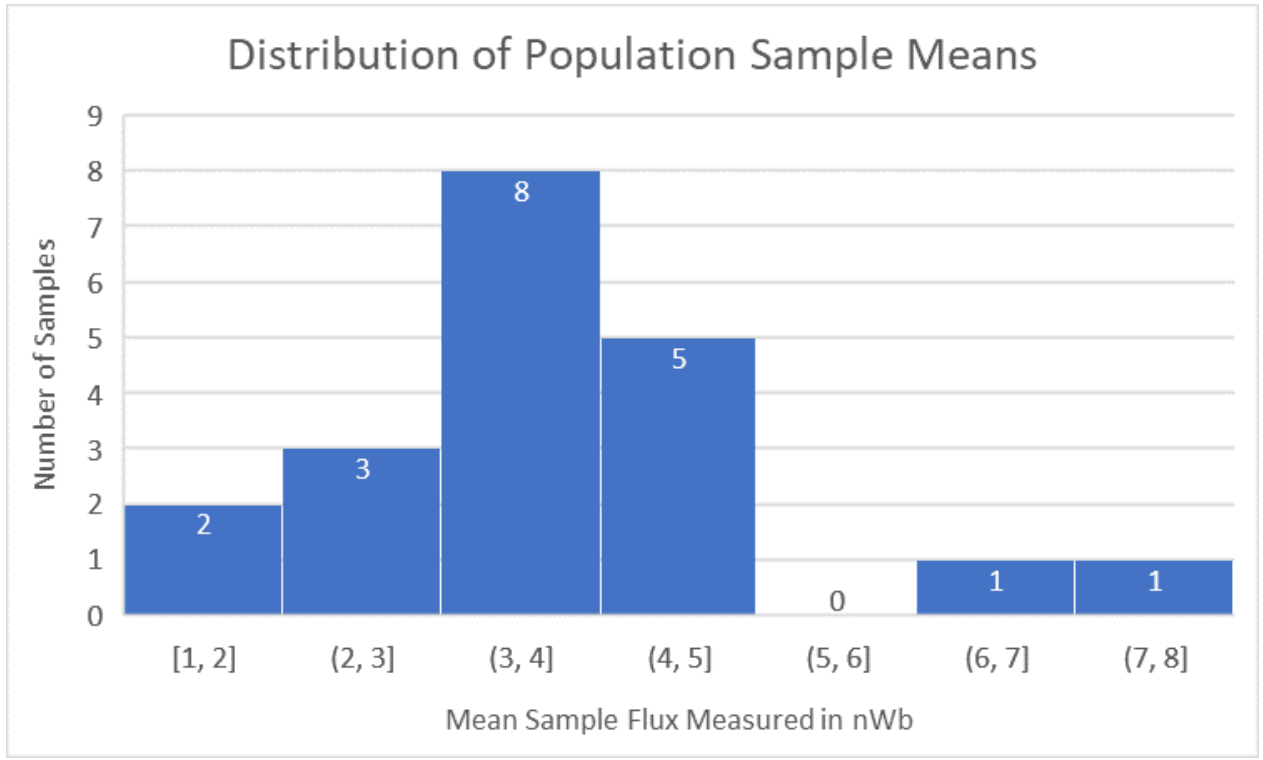
Results

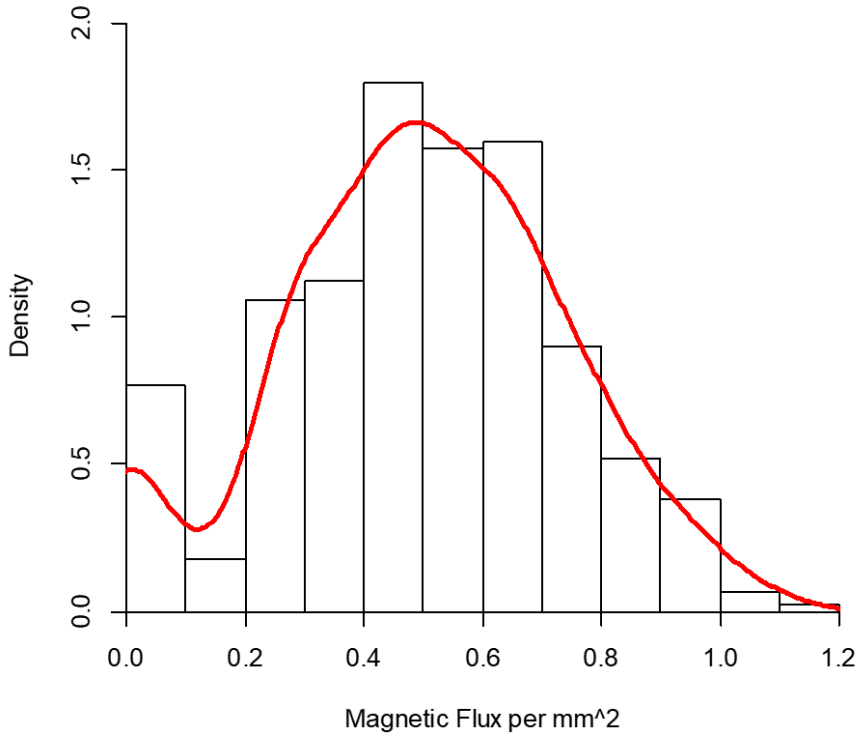
- Precision and Bias
- Interferences and Matrix Effects

Validation Parameters	Results
LOD	*Previously assessed - Magnetic particles visible but no measured response
LOQ	*Previously assessed - Magnetic particles visible and measurement value 1 nWb
Precision	2.3%-9.1%
Bias	2.1%-8.7%
Suppression/Enhancement	*Previously assessed – hysteresis effects, biasing induction current effects
Sample Stability	*Previously assessed – stable long-term
Interferences	No impact on measurements
Matrix Effects	No impact on measurements

Results

- Population





Conclusions

- Magnetic flux measurement method validation can be conducted successfully, with precision and bias within acceptable ranges
- No matrix effects or interferences were found to occur
- Magnetic flux measurements provide the potential for a robust, non-destructive toner examination method

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Questions

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