ViennaMagnetics
ADVANCED MAGNETIC TESTING

>accuracy through physical consistency<

patents granted / pending
standardization initiated

ViennaMagnetics Note of Feb.1, 2023

VM Precision Multi-frequency Single Sheet Tester

General + Data

+ Results for FeSi for 1 kHz, + for amorphous ribbons up to 10 kHz

Now all technical details on *16 printed pages* *open access* in
American Institute of Physics (AIP) Advances 12, 10.5208, pp.1-16 (2022):
Physically consistent multi-frequency magnetic loss testing
for FeSi and for amorphous ribbons (ARs)

The **Vienna*Magnetics* Precision Multi-frequency Single Sheet Tester** is a simple and rapid desktop apparatus, for physically correct measurements of magnetic losses of electric steel + amorphous ribbons, for up to 10 kHz, at a sample of 50 cm x 17 cm (*N* times 45 cm x 17 cm for AR) – compact, precise *and* industrially representative

Preconditions

At present, for FeSi, two internationally IEC-standardized test systems are available for low (so-called technical) frequencies of 50 Hz, or 60 Hz, respectively:

(i) The **Epstein Frame** (IEC 60404-2) for about two dozens of sample strips of 28 cm x 3 cm size –
+ compact + affordable + standardized
- *indirect* Watt-metric measurement, from total power consumption of the inhomogeneous magnetic frame
- time consuming sample preparation and handling
- errors from slitting and annealing

(ii) The **Single Sheet Tester** (SST; IEC 60404-3) for a steel sample of 50 cm x 50 cm size –
+ high reproducibility
+ standardized (but results differing from Epstein)
- absolute accuracy unknown
- *indirect* loss determination, as for Epstein
- large apparatus of high mass and cost
for ARs: EN IEC 60404-16

The VM Multi-frequency Single Sheet Tester (VM MF-SST)

- an internationally first precise multi-frequency magnetic loss tester, for an industrially representative sample formats (50 cm x 17 cm for FeSi, 45 cm x 17 cm or less for amorphous ribbons)
- for precise loss tests of transformer core steel or amorphous ribbons, for frequencies up to 1000 Hz, for the full induction range, up to 1.8 T (depending on material)
- for 50 Hz, results for FeSi close to Standard SST
- for e-drive materials and ARs, also for high frequencies, up to 10 kHz, for max. losses up to 200 W/kg
- physical consistency, for high absolute accuracy
- ultra-rapid performance of measurement

Advantages of VM Multi-frequency SST, versus Standard SST for FeSi

- strongly enlarged range of frequency
- extreme reduction of mass, by means of a small high-frequency yoke
- reduced size of - desktop-compatible - apparatus, by means of reduced sample width to 17 cm, as being sufficient for the homogeneous structure of modern steel types (50 cm sample length, like IEC Standard 60404-3)
- more exact true-field air-flux compensation
- simplified, rapid test procedures (more than 10 measurements per minute possible)
- automatic scan over large induction range
- instantaneous power functions, as an option
- instant output of results by laptop PC, as well as by A4 protocol printer
  (extra data processing possible via text files)

Applicability also for amorphous ribbons

Induction Synthetization as an option -
Instantaneous and time-averaged losses can be analyzed, e.g., for flux distortion
(defining e.g. 5000 points for 50 Hz)

Summary - A completely novel solution, for *direct*, simple, accurate, rapid and cost-effective measurements of losses, over a very large frequency range,
for all types of material, i.e. NO and GO FeSi, as well as amorphous or nano-crystalline ribbons

Photo of Test System -

see also Video on **www.viennamagnetics.eu**

All-inclusive version of tester (ca. 80 cm x 55 cm x 19 cm; ca. 40 kg)
Included periphery: lap-top PC and protocol printer

Technical Data of MF-SST **(updated)**

Updated Test Ranges

Losses, time-averaged	0.1 ... 200 W/kg
Losses, instantaneous	0.01 … 400 W/kg
Frequency	
Series *Basic*	50 Hz ... 500 Hz
Series *Standard*	50 Hz ... 1 kHz
Series *Extended*	16 2/3 Hz ... 10 kHz (according to request)
Induction	0.05 T …1.8 T; max. 1.9 T (depending on material and frequency)
Magnetic field strength	up to 10 kA/m short-time
Absolute accuracy	ca. 2 % estimation for losses of flat sample, for technical frequencies
Repeatability	ca. 0.2 % (for flat sample, including turn-over)

This results from a concentration to the homogeneously magnetized sample region. It shows a 1D Maxwell/Poynting-Field, as a precondition for a **physically correct, consistent *direct* determination of losses**. A Watt-metric power measurement at inhomogeneous magnetic circle is avoided. The applied HF magnetization yoke has no direct impact on the results of measurement.

Best Alternative to Epstein Frame –

- total test system even more compact
- similar costs of purchase
- lower costs of man power (simple procedure)
- more correct results (+ no shearing effects)

Examples of test results in the following graphs

see next pages

Example of protocol for FeSi for 1 kHz

for a test on grain-oriented steel, magnetized from 0.05 T up to 1.9 T

sample under test	width (mm)	length (mm)	density (kg/m3)	mass (g)	thickness (µm)
GO11	170	500	7650	143	220

frequency	upper *B*-value	lower *B*-value
1000 Hz	1.9 T	0.05 T

RESULTS:

f (Hz)	*B* (T)	*FF* (-)	rating	H_{RMS} (A/m)	*H* (A/m)	*µ*/1000 (-)	p_{OR} (W/kg)	P_{MAX} (W/kg)	*P* (W/kg)
1000	1.9	1.111	2	288.7	734.2	2.06	-99.557	286.02	146.12
1000	1.8	1.111	1	158.1	282.5	5.08	-25.922	240.67	123.85
1000	1.7	1.111	1	122.2	168.7	8.03	-8.340	197.45	104.49
1000	1.6	1.111	1	105.1	150.6	8.46	-3.548	161.05	88.281
1000	1.5	1.111	1	93.4	133.9	8.92	-2.051	132.01	75.042
1000	1.4	1.111	1	83.9	118.2	9.44	-1.430	109.10	63.895
1000	1.3	1.111	1	75.9	103.7	9.99	-1.128	91.764	54.315
1000	1.2	1.111	1	68.9	91.3	10.48	-0.959	78.953	46.020
1000	1.1	1.111	1	62.8	81.5	10.77	-0.862	68.331	38.724
1000	1	1.111	1	57.3	73.9	10.80	-0.804	58.543	32.234
1000	0.9	1.111	1	52.2	68.1	10.56	-0.748	49.350	26.482
1000	0.8	1.111	1	47.3	62.6	10.20	-0.672	40.589	21.301
1000	0.7	1.111	1	42.4	57.0	9.81	-0.596	32.339	16.676
1000	0.6	1.111	1	37.4	50.8	9.43	-0.499	24.700	12.582
1000	0.5	1.111	1	32.3	44.2	9.05	-0.393	17.873	9.036
1000	0.4	1.111	1	27.0	37.1	8.65	-0.291	11.982	6.029
1000	0.3	1.111	1	21.4	29.4	8.18	-0.195	7.156	3.573
1000	0.2	1.111	2	15.3	21.2	7.60	-0.108	3.422	1.689
1000	0.15	1.111	2	11.9	16.7	7.28	-0.071	2.024	0.987
1000	0.1	1.111	2	8.3	11.6	7.02	-0.037	0.936	0.455
1000	0.05	1.111	2	4.4	6.2	6.71	-0.012	0.256	0.123

Contained data (updated):

f frequency
B peak value of induction
FF form factor of induction (1.111 for precise sinusoidal induction)
rating (= 1 for ideal physical conditions)
H_{RMS} RMS value of magnetic field strength
H peak value of field
µ relative AM permeability
p_{OR} orientation power (measure for texture;
inverse to spin alignment, due to grain dis-orientations)
P_{MAX} maximum of instantaneous losses
P losses (time-averaged)

Examples of results for Fe-based amorphous ribbons (25 Hz - 10 kHz)

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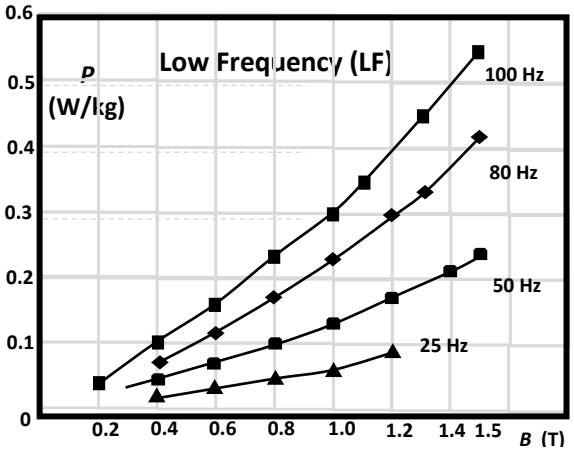

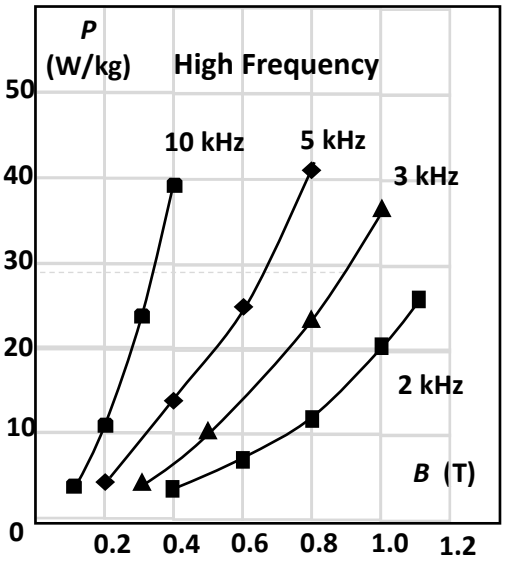

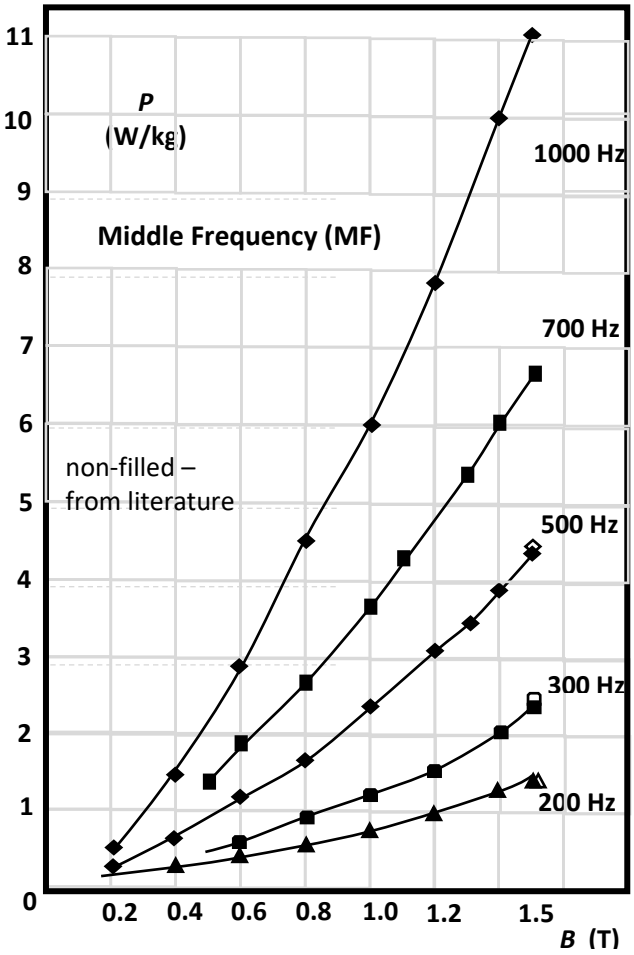

Our Salzburg Test Service:

Rapid **multi-frequency AM measurements**
+ analyses for **rotational magnetization** + sample management for follow-up investigations

For rapid tests, send to Bad Gastein your samples:
50 cm x 17 cm for FeSi
45 cm x 17 cm (e.g. *N* = 6 sheets) for amorphous ribbons (minimum mass 5 g)
8 cm hexagonal for Rotational Magnetization (on request)

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