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A New Application of Transient Recorder to Magnetic Measurements (Part I: Core Loss Measurement at Very Low Frequencies)

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Synopsis

A new method have been developed based upon analogue-to-digital conversion techniques and memories. The method involves the scaling of operating frequency from "real" to "optimum" for the power loss measurement. The advantages of using this techniques are as follows: (1) extreme availability at lower frequency region, (2) high accuracy and high stability, (3) simple measuring procedure, (4) digital indication.

This method can be measured the power losses over the frequency range 0.1Hz to 1kHz for magnetic circuit and d.c. to 1kHz in such a purely resistive circuit. We estimate the accuracy of this core loss measuring system within 1.0% over all these frequency range. Using this system, specific core losses of the various grades of silicon iron have been measured in the frequency range 0.1Hz to 200Hz.

1. INTRODUCTION

The flux waveform in a transformer core is locally distorted even if the total flux waveform is sinusoidal. In order to estimate the iron loss in such a core, total loss is separated into hysteresis and eddy current components. The customary method of loss separation is not always applicable to highly oriented silicon-iron.

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Otherwise, some experimental attack have been done to measure the behavior of lower frequency anomalous non-liniality.[1],[2],[3] But, all of those techniques for iron loss measurement are complicated and accuracy is not satisfactory. This point of view, the accurate measurement at very low frequency is important in investigating anomalous loss. But it is difficult, because the frequency characteristics of measuring apparatus are not satisfactory at lower region.

We have used equipment which memorize waveforms, for the measurement of the flux distribution in a transformer core.[4] It was found that this equipment can be used as a frequency converter. Using this converter combined with the conventional measuring apparatus used at commercial frequencies, the iron losses in the very low frequency region can be measured simply and accurately.

2. Measuring Circuit

A simplified block diagram of the measuring system is shown in Fig. 1. The supply to the magnetizing circuit is obtained from a d.c.

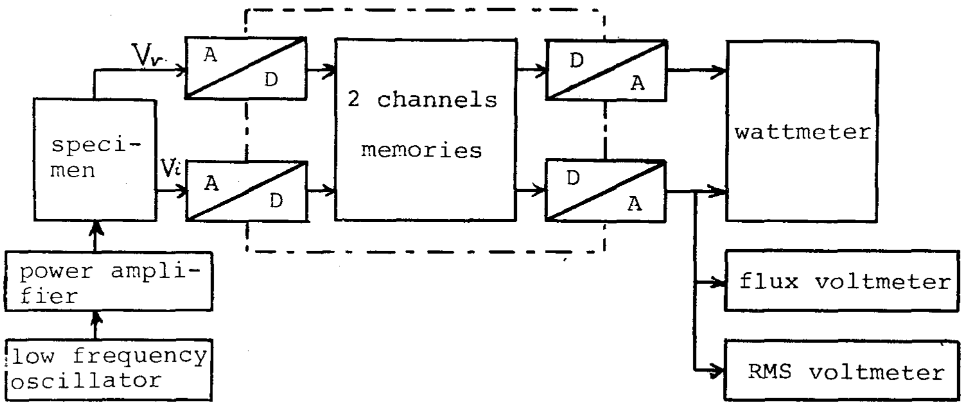


Fig. 1. Block diagram of measuring circuit.

power amplifier, excited from a low frequency oscillator. As the flux waveform is distorted at very low frequencies, the induced harmonic components of the search coil waveform are fedback to the input of the power amplifier. The search coil supplies both the feedback signal and the input voltage V_v of the analogue-to-digital(A/D) converter. A shunt resistance is connected in series with the magnetizing winding to obtain the voltage V_i. The area inside the chain line shows the digital circuit which incrases or decreases the frequency of the input voltage making it suitable for the wattmeter.

The measuring procedure is as follows:

(1) Two analogue voltages V_v and V_i corresponding to the output voltage and exciting current of the specimen are stored in the two channel, 8 bits, 1000 words IC memories after passing through the A/D converters.

(2) These voltage waveforms stored in digital form are read out through digital-to-analogue(D/A) converters at the standard frequency, for example 50Hz.

(3) The output voltages of these D/A converters are multiplied together using a time division multiplier-type wattmeter.[5]

A digital type mean voltmeter is used for the measurement of flux density, and a digital type root mean square voltmeter is used for the measurement of the form factor.

The conversion ratio of the frequency is freely chosen by adjusting the rate of the reading and writing speed. The writing and reading speeds of this equipment are independently adjustable in the range of 1μsec/word to 1sec/word. The writing speed must be selected so that exactly one wave length or a multiple of one wave length can be stored. If this leaves something over, the full waveform can not be read out repeatly. The number of waves to be memorized must be chosen as small as possible in order to get a smooth waveform, when it is read out.

The minimum frequency which can be measured using this system is in principle limited to 0.001Hz. Because the minimum writing speed is 1sec/word. It is also limited by the waveform distortion and the noise in the search coil due to the small induced voltage for iron loss measurement.

The maximum frequency which can be measured is limited by the number of samples per cycle. Excessive notches in the waveform might cause an error. If the number of samples per cycle is greater than 500, the notches in the waveform due to sampling is negligibly small as can be seen in Fig. 2. We can not measure any difference between the input waveform of the A/D converter and the output of the D/A converter. The frequency of this input waveform is 0.1Hz, and that of the output is

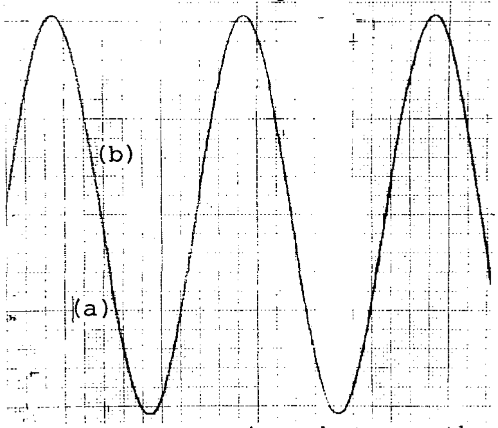


Fig. 2. Comparison between the A/D input and D/A output voltage waveforms plotted on an XY recorder.
(a) 0.1Hz (input)
(b) 100Hz (output)

being converted to 100Hz. The writing speed is 20msec/word and the reading speed is 20μsec/word.

3. Accuracy

Two principal causes of error for this measuring system can be considered.

(1) The quantitization-error of the digital circuit.
This value is within ±0.2% for the 8 bits.

(2) The error of the wattmeter.
This value is approximately within ±0.1%.

The other factors of error, namely, shunt resistance, noise and offset, etc, in the system can be avoided by sufficient precalibration.

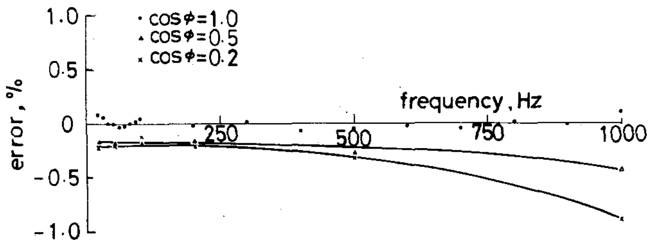


Fig. 3. Power factor errors as a function of frequencies.

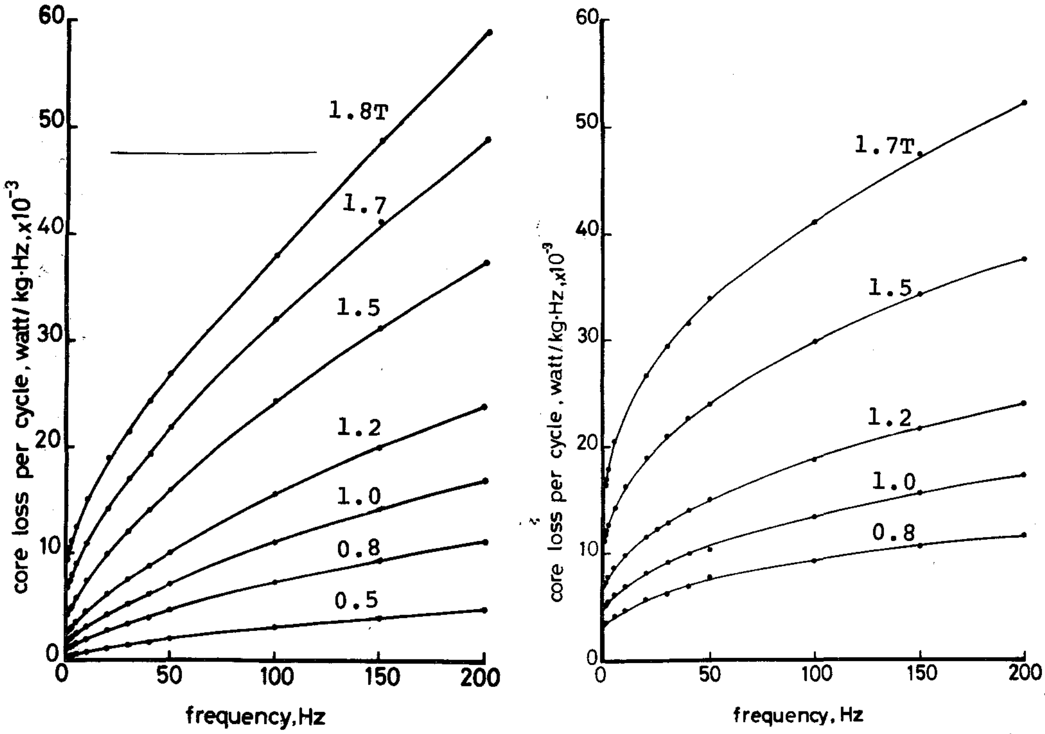
Figure 3. shows the relative errors due to power factors as a function of frequency obtained from direct comparision between our method and standard one.

We estimate the accuracy of this core loss measuring system is within 1% over the frequency range 0.1Hz to 1kHz.

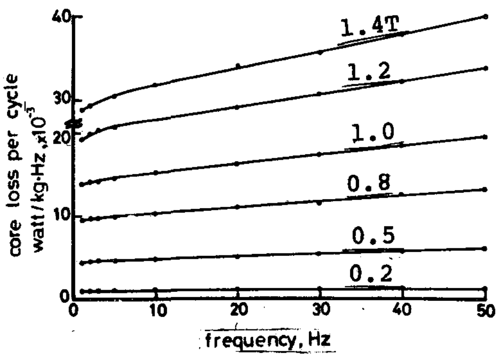
4. Measurements of Losses in Silicon-Iron

4.1 Experimental Results

The typical results of iron loss measurement using this technique shown in Fig. 4. (a) and (b) are obtained from a 25cm Epstein square built up of the 0.3mm thick highly oriented silicon-iron which is the so called "HI-B" and 0.35mm thick convertional non-oriented silicon iron respectively. Figure 4(c) is obtained from a laminated core made from the 0.1mm thick cube textured silicon-iron. The core configuration is shown in Fig. 5. The exciting winding and the search coil are directly wound on a protecting frame by which the core is protected from external stress. Each lamination has



(a) (c)



(b)

Fig. 4. Core loss per cycle as a function of frequency.

(a) Grain-oriented core (HI-B), 0.30mm(thick)

(b) Non-oriented core (S 10), 0.35mm(thick)

(c) Cube-textured core, 0.1mm(thick)

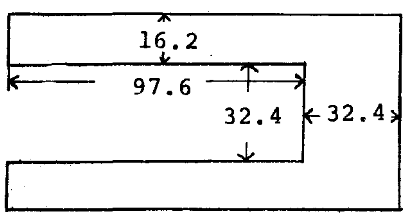


Fig. 5. Dimension of cube

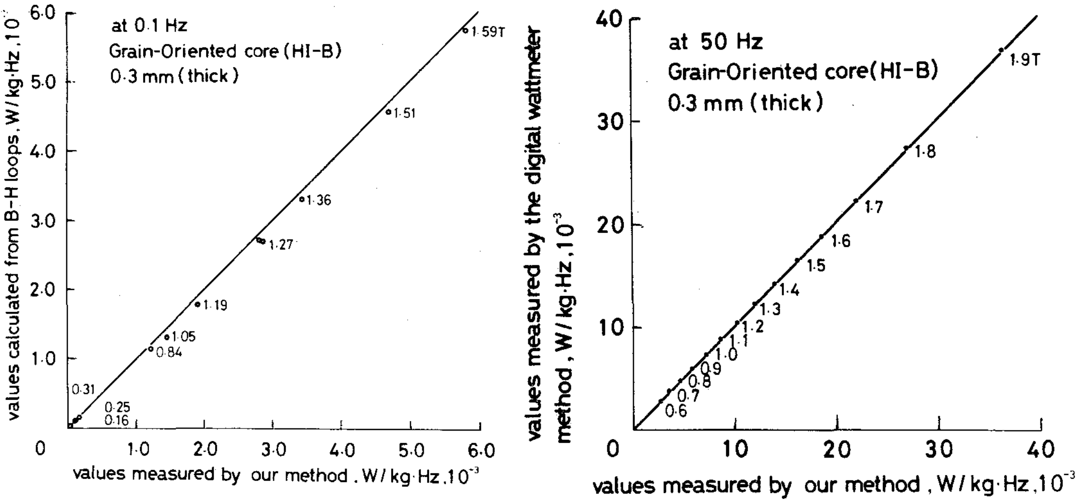
varnished insulation. The effective mass factor which has been measured by Narita[6] using the comparative method is used to calculate the mass.

Using the test frequency, demagnetization has been done for all specimen.

The downward curvature of the loss versus frequency characteristics fell much with the higher magnitude of the flux density.

4.2 Comparison between other techniques

At very low frequency, for example 0.1Hz, losses can be calculated from the area of B-H loops. Figure 6(a) shows the



(a) (b)

Fig. 6. Relationship between values measured by our method and other techniques for the magnetization at 0.1Hz and 50Hz.

relationship between the values measured by our method and the values calcurated. In this case, flux waveform distortion has been occured, but no account requires because the measurement has been done simultaniously during the XY recorder traces the loop. Figure 6(b) shows the direct comparison between the values measured by our method and the values measured by the digital wattmeter. In these results, it is shown that the differences of measured values between both methods were within 5% in Fig. 6(a) and within 1% in Fig. 6(b).

In former case, it seems the errors caused by the recorder and the planimeter take large parts.

5. Conclusions

Using our method results have obtained in the frequency range d.c. to 1kHz for a purely resistive circuit and 0.1Hz to 200Hz for a magnetic circuit.

It is anticipated that the accuracy of the experimental results will contribute to further discussions concerning the nature and magnitude of the anomalous loss.

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