HIGHER FREQUENCY MAGNETIC SINGLE SHEET TESTER

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Summary Testing of magnetic properties of amorphous and nanocrystaline materials at AC magnetization represents very complicated problem of open specimen homogeneous magnetizing with the exactly defined magnetic flux waveform, the precise conversion of magnetic variables to the electrical ones and the measurement of integral values of strongly distored electrical variables. Difficulties of these measurements are increasing with increasing frequency. The new Single Sheet Tester (SST) for open specimen magnetic measurement up to frequency 20 kHz has been developed at CTU in Prague, Dept. of Circuit Theory. The new SST consists from the yoke with MMF compensation, and the power amplifier for excitation up to magnitude 100 V and currents up to 3 A at frequencies from 1 kHz to 20 kHz. The control and measuring system is completely digitized and the core of it is based on PC plug-in cards. The paper presents the basic ideas of SST design and the first practical experience with the realized SST prototype.

1. INTRODUCTION

For measurement of the AC magnetic properties of the classical soft magnetic materials (e.g. silicon steels) frequency range from 50 up to 500 Hz is required. Open specimens can be measured either in the Epstein frame and/or by the single sheet or single strip testers (SSTs). The theoretical analysis and practical experience show that the best results gives the original Czech method of automatic compensation of MMF along the magnetizing yoke and air gaps with the Rogowski Chattock potentiometer as a zero indicator (see [1]).

Modern magnetic materials are designed for frequency up to 100 kHz. Therefore the frequency range of AC magnetic measuring device must be extended. To fulfil the new requirements it is necessary to design new types of single sheet and/or single strip testers.

There are many difficulties in designing and realizing precise testing device for amorphous and nanocrystaline materials at AC magnetization. Required higher frequencies cause other additional problems. To reach sufficient accuracy of the measurement three basic problems must be solved. First it is necessary to ensure homogenous magnetic field into the specimen measured part with defined magnetic flux waveform (in most cases sinusoidal). Second, we must ensure precise conversion of magnetic variables to the corresponding electrical variables. The third problem represents the precise measurement of integral values of strongly distorted electrical variables. Solving of all three mentioned problems will be more difficult when frequency is going up.

In this article it is described a new prototype of the compensated single strip tester that has been developed at the Czech Technical University in Prague. This tester is fully controlled by PC and its measuring system is completely digitized. Using of the MMF compensation method gives a possibility to measure magnetic field strength by the same way as for close specimens. In this case the magnetic field strength is directly proportional to the magnetizing current. The developed tester prototype can measure the magnetic properties of soft magnetic materials for frequency up to 20 kHz.

2. NEW ARRANGEMENT OF THE SST TESTER

The compensated single strip tester consists of three main blocks - the control PC with additional plug-in cards, the exciting and measuring electronic circuits, and the magnetizing device (i.e. a yoke with a set of windings), see Fig. 1.

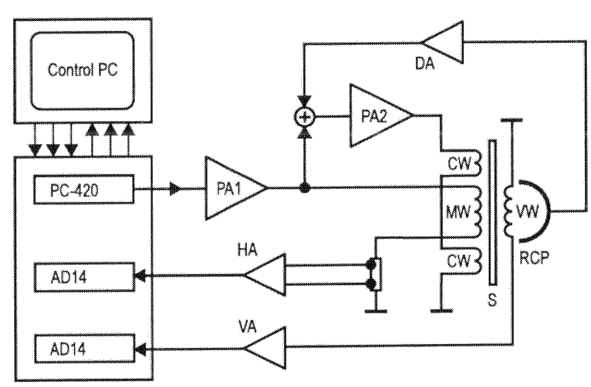

Fig.1. Block diagram of the SST tester.

The personal computer (PC) completely controls functions of the tester and ensure measured data processing. The PC is equipped by three additional plug-in cards and by the special control software. The first card, programmable generator PC-420 (fy Datel), serves for exciting of the power magnetizing amplifier by voltage with an arbitrary waveform. Signal from this card drive the main magnetizing amplifier. The two same A/D cards digitize signals proportional to the basic magnetic quantities dB/dt (the voltage u_i(t)induced in the voltage winding) and H(t) (the voltage corresponding to the magnetic field strength waveform). The special developed software ensures setting up of exciting values and parameters of the magnetizing and measuring process. This software also provides processing and visualization of measured data (magnitudes of magnetic flux density B_a, and magnetic field strength H_a and its waveforms, specific power losses p, the hysteresis loop, etc.).

The signals from and to the PC are connected to the block of electronics. This block contains magnetizing and compensating power amplifiers, measuring circuits for conversion of dB/dt) and $H(t)$ waveforms to the corresponding electrical values and feed-back circuits for MMF compensation. As power amplifiers are used two MOS-FET operational amplifiers MP38 (Apex comp.). These high voltage MOS-FET operational amplifiers are especially designed for motor drivers, ultra-sonic transducer drivers and also for yoke/magnetic field excitation. The MP38 hybrid power amplifier is constructed with surface mounted components on a thermally conductive and electrically isolating substrate. The maximal internal dissipating power is 125 W, the maximum supply voltage is ± 100 V symmetrically, maximum output current is 10 A. The power amplifier is also equipped by current limiting circuit and its stability can be settled by external compensating elements. Typical power bandwidth is 20 kHz, transit frequency around 1 MHz. The application of the mentioned integrated circuit is very convenient, because it is designed especially to drive loads with no negligible reactive component.

The magnetic field strength is measured by taking-off the voltage drop on the non-inductive resistor connected in series with the magnetizing winding MW. The block of electronics also contains the circuits for voltage winding (VW) induced voltage amplification. MMF compensation feedback loop consists of the Rogowski-Chattock potentiometer (RCP), differential amplifier DA and power amplifier PA2 driving the compensation winding CW.

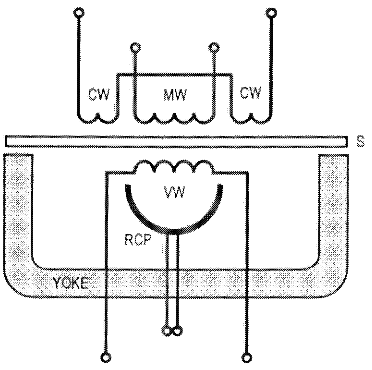

Fig.2. SST yoke arrangement.

The third main part of the SST tester represents the magnetizing device consisting of a yoke and a set of windings. This magnetizing equipment has to be designed according to the desired wider frequency range and to the maximal output ratings of the power amplifiers, see Fig. 2.

The measured specimen (a strip of a soft magnetic material with the width up to 30 mm and the length over 250 mm) is a part of the magnetic circuit and must be inserted into the inner space of the windings former. The magnetic circuit is completed by the soft magnetic yoke with the sufficient cross section area. The magnetizing equipment is equipped by two independent sets of windings for two different ranges of frequency. Each set of windings consist of the main magnetizing winding MW, measuring voltage winding VW and compensating winding CW. These three windings surround the measured specimen. The first set of windings is designed for frequencies from 1 kHz to 20 kHz, the second set for frequencies from 10 kHz to 100 kHz. Windings creating the first (second) set have the following number of turns: MW 40 (10), VW 40 (40), CW 40 (10). The length of the magnetized part of the specimen is 200 mm and the length of the central measured part is 100 mm. The Rogowski-Chattock potentiometer encloses the central measured part of the specimen and it measures the difference between MMF of magnetizing winding and the magnetic voltage along the specimen measured part.

3. EXPERIMENTAL RESULTS

The new compensated single strip tester was realized and successfully tested for measurement of electromagnetic properties of strips of amorphous magnetic material with the cross section area equal 20 x 0,03 mm. The frequency range of measurement was extended up to 20 kHz using the stroboscopic sampling of 64 periods of the measured quantities.

The first experiments made without the algorithm for magnetic flux waveform compensation gave the acceptable accuracy of the induced voltage form factor (less than 5 percent distortion) up to the magnetic field strength H_a = 500 A/m. The analogue MMF compensation loop with the gain 30 dB was stable and the uncertainty of the specific power losses due to this limited gain was less than 3 % (for $Ha \leq 500$ A/m).

4. CONCLUSION

The theoretical analysis and experimental results obtained during prototype testing fulfil the achievement that using of the feedback compensation method for SST design is the proper way how to extend the accuracy and the frequency range for testing of new soft magnetic materials with extremely high permeability and very small power losses. The application of digital algorithm for magnetic flux waveform control and for the MMF compensation will probably extend the possible magnetization up to saturation.

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