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AT LOW FREQUENCY**

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**PUBLICAÇÃO IPEN 5
IPEN - Pub - 5**

NOVEMBRO/1979

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CENTRO DE METALURGIA NUCLEAR
CMN 72

INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES
SÃO PAULO - BRASIL

Série PUBLICAÇÃO IPEN

INIS Categories and Descriptors

E42

INTERNAL FRICTION: Measuring methods
MEASURING METHODS: Internal
ELECTRONIC EQUIPMENT

AN AUTOMATIC MEASURING SYSTEM OF INTERNAL FRICTION AT LOW FREQUENCY

Kunihiko Iwasaki¹

ABSTRACT

An inverted torsion pendulum is automatized by means of Tectanel electronic system. Internal friction and the period of vibration are measured fully automatically as a function of temperature and the obtained data are analysed with a computer.

1 – INTRODUCTION

Internal friction is known to be a very powerful tool for the study of the dynamical properties of some kinds of lattice defects^(1,4). It is also important from the practical point of view. High damping alloys, for example, have recently been investigated intensively, because they are expected to suppress noises and vibrations without using special additional absorbers⁽⁵⁾.

As the measurement of internal friction is usually a time-consuming work, it is highly desired to make the measuring system fully automatic. In this paper a fully automatic system with the use of Tectanel electronic system² is presented. This system is applied to a torsion pendulum and the obtained data are analysed with a computer.

2 – AUTOMATIC SYSTEM

The block diagram of the whole system is shown in Figure 1. The pendulum used is a usual inverted torsion pendulum the details of which have been described elsewhere⁽³⁾. A well collimated beam from the light source is reflected on the mirror attached to the moving suspension rod of the pendulum and goes to a photo tracer (Photodyne Type PHA), in which a photo cell with a pen follows the position of the light and records its trace on paper. This recorded trace which was used to measure the vibrational amplitude in analog form in the previous non-automatic system is now used only for monitoring.

An electrical signal which is proportional to the velocity of the photo cell can be taken out from the photo tracer. As this signal is regarded to be also proportional to the vibrational amplitude except the phase difference of 90° , it is used as an input signal of the system. After passing through a low pass filter the signal is amplified by a detection preamplifier (Tectanel PD 1) and then goes to an

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Approved for publication in July 1979.

Writing, orthography, concepts and final revision are of exclusive responsibility of the Authors.

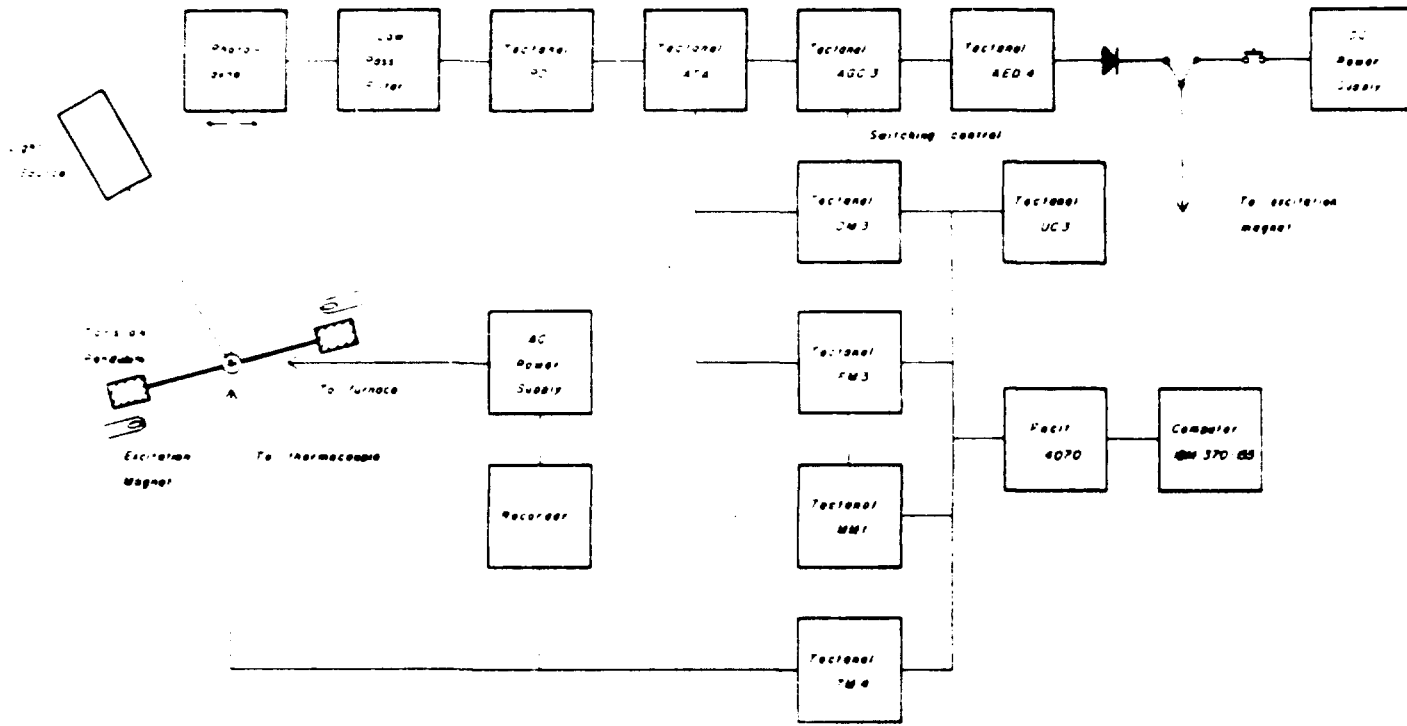


Figure 1 - Block Diagram of the Automatic Measuring System Where the Pendulum is Shown Only Schematic. 11v

automatic tuned amplifier (Tectanel ATA 1) which acts as an active filter and allows only the signal of frequency range between 0.5 and 1.5 Hz to pass through it with a quality factor Q of about 10. The allowed frequency range and the quality factor can be changed by replacing some of the condensers and the resistances of ATA 1. The obtained filtered signal is then divided into two, one for the excitation system and the other for the measuring system.

The automatic excitation system consists of an automatic gain controlled amplifier (Tectanel AGC 3) and an excitation amplifier (Tectanel AED 4). The former controls its gain automatically so that the vibrational strain amplitude of the specimen may be kept constant. The latter is a power amplifier for the excitation magnet. If the input signal of AGC 3 is larger than the reference value, the gain of AGC 3 decreases automatically to suppress the excitation current for the magnet and vice versa. The vibrational strain amplitude of the specimen can therefore be changed in the range between 10^{-6} and 10^{-4} by adjusting the gain of PD 1. If the gain is increased, the input signal of AGC 3 also increases to make the amplitude decrease. As the measurement of internal friction is made by a free decay method as will be described later, the excitation stops during the measurement of amplitude. A silicon diode is put at the output of AED 4 so that the excitation current may flow only for the half cycle which is effective for the excitation of the specimen. A DC power supply is used for the manual excitation which is necessary at the beginning of experiment.

The measurement system consists of a decrement meter (Tectanel DM 3), a frequency/period meter (Tectanel FM 3), a temporary memory (Tectanel MM 1) and a temperature measuring device (Tectanel TM 4). All these apparatuses are controlled by a control unit (Tectanel UC 3) which determines the measuring sequence and the recurrence time. The measuring sequence is shown in Figure 2. DM 3 measures the vibrational amplitude during free decay, for example, it measure the initial amplitude Q_0 and the n-th amplitude Q_n . During this measurement the excitation stops automatically by means of a switching control settled between AGC 3 and DM 3. The period of vibration F is measured simultaneously with the amplitude with FM 3 and the result is temporarily stored in MM 1. Temperature (thermo-electromotive force of a thermocouple) is measured with TM 4 before (T1) and after (T2) the amplitude measurement. A constant voltage of 10.00 mV is added to the thermo-electromotive force in order to avoid the trouble of changing the polarity when the temperature crosses 0°C . Temperature is raised continuously at a rate of about $1^{\circ}\text{C}/\text{min}$ by gradually increasing the voltage of an AC power supply for the furnace. The thermo-electromotive force and the voltage of the AC power supply are monitored with a multi-pen recorder. All the measured digital data are recorded with a tape puncher (Facit 4070) according to the USASCII code in the sequence of T1, Q_0 , Q_n , T2, F as shown in Table I where decimal prints are abbreviated.

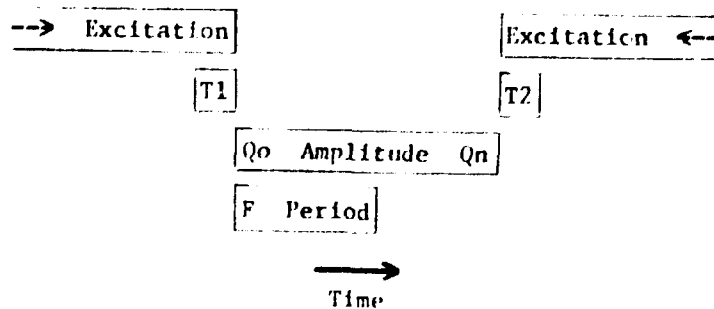


Figure 2 - The Measuring Sequence of the System. This Cycle is Repeated as the Temperature is Increased or Decreased

Table I

An Example of the Final Form of the Table of the Experimental Data Analysed with a Computer. Only the First and the Last Few Lines are Shown

S T A T I S T I C A L A N A L Y S I S S Y S T E M							11 53 THURSDAY, MAY 10, 1979	
OBS	T1	Q0	Q50	T2	F	D	X	C
1	473	5073	3333	473	125098	0.0026743	-5.270	-171.50
2	476	5012	3271	479	125122	0.0027168	-5.225	-169.25
3	480	4952	3187	483	125183	0.0028057	-5.185	-167.25
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
117	1074	5009	4384	1081	128451	0.0008485	0.775	19.375
118	1084	5015	4377	1090	128481	0.0008663	0.870	21.750
119	1093	5005	4367	1098	128495	0.0008681	0.955	23.875

The data are analysed with a computer (IBM 370 155). Internal friction D is obtained from Q_0 and Q_n by the following relation,

$$D = \frac{1}{n\pi} \ln \frac{Q_0}{Q_n} \quad (1)$$

where $n = 50$ is usually used. As for temperature the computer first averages the values of T_1 and T_2 and subtracts 10.00 mV from it (denoted by X in Table I). The obtained real thermo-electromotive force is then changed into temperature (C) by referring to the table of thermo-electromotive force vs temperature which is stored in the computer at every $1^\circ C$ step. Inbetween temperatures are obtained by linear interpolation. Finally a table which contains all the measured data T_1 , Q_0 , Q_n , T_2 and F and the calculated values D and C and figures in which D and F are plotted with respect to C are obtained with a line printer. The examples are shown in Table I and Figures 3 and 4. As the line printer has fixed line spaces and strokes, it can not print the symbols in arbitrary positions. Therefore the nearest possible positions are chosen for each measuring point and they are printed in those positions. Consequently subtle variation of the experimental data can not be detected in the figures drawn with a line printer. For example, printed points frequently lie on straight horizontal lines as shown in Figures 3 and 4 though the actual values are slightly different from each other. This kind of figures, however, are very useful to grasp the outline of the data rapidly. More precise figures are of course possible to obtain if an X-Y plotter is used.

3 – DISCUSSIONS

Some problems and troubles which we encountered are described and the possible methods to improve them are discussed here.

When the vibrational strain amplitude is very small, in the range of 10^{-6} , the signal to noise ratio also becomes very small and reliable internal friction data can not be obtained if only Q_0 and Q_n are used. In such a case the following two alternative methods are very useful to make the scattering of the internal friction data smaller.

- 1) Take a group of amplitudes $Q_0 + Q_1 + \dots + Q_m$ and $Q_n + Q_{n+1} + \dots + Q_{n+m}$, where possible m is 1, 4 or 9, as the initial and the n -th amplitude, respectively, and calculate the internal friction according to Eq. (1) without changing the program of the computer.
- 2) Take all the amplitudes Q_0, Q_1, \dots, Q_n and plot $\ln Q_i$ vs i to find a best fit slope by the method of least squares. This slope divided by $-\pi$ gives the internal friction. In this case the program of the computer must be changed slightly.

As the strain amplitude lies usually in the range of 10^{-5} , it is sufficient to take only Q_0 and Q_n in the normal experimental conditions.

A photo tracer is now used as a source of vibrational signal. As the signal from it is a velocity sensitive one, the zero point adjusting mechanism is unnecessary (when the temperature is changed, the zero point of the specimen vibration usually moves a little, especially in deformed state). Though this is a great merit for making the system simple, the motion of the photo cell is not smooth enough to get a well-shaped sinusoidal wave. The signal is then distorted and this is one of the main causes of the errors. The filters used here are effective only for high frequency noises and can not improve the distortion of the signal. In order to remove this effect a new signal detection system with a CDS twin photo cell⁽²⁾, which contains no mechanical part, is being made in our laboratory.

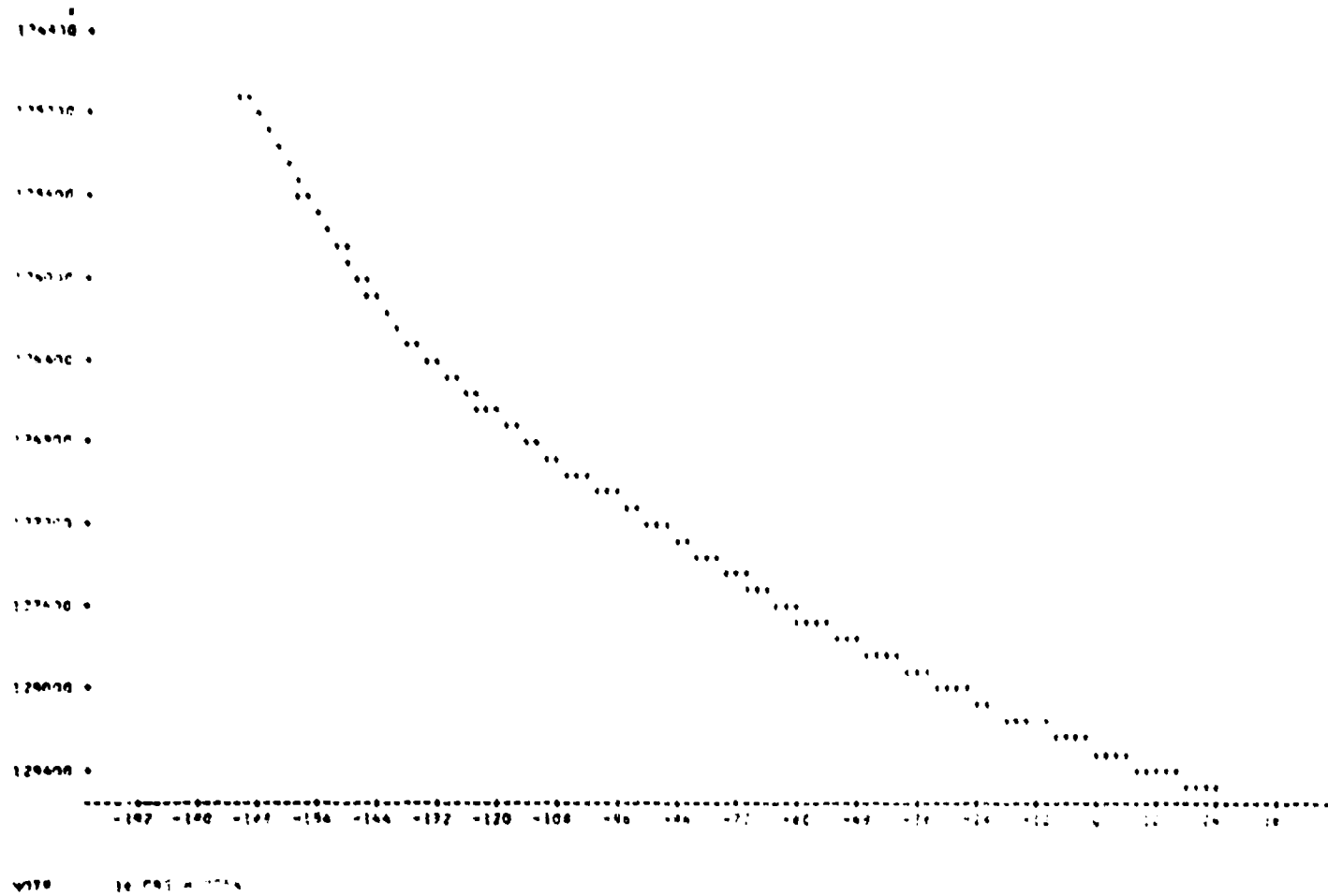


Figure 4 - An Example of the Experimental Data on Pure Nb Where the Period of Vibration is Plotted Against Temperature with a Line Printer

As for other noises, the Tectanel system is very sensitive to a switching or pulse noise. Therefore such electronic devices as triacs and thyristors are very difficult to use as controllers of power supply for the furnace. They can easily lead to mistripping of the Tectanel system, especially in the measurement of the period of vibration. A simple slidac (continuously variable transformer) seems to be better than power supply controlled with triacs or thyristors.

Though the system has some defects at the present stage, it is a great merit of this system that more detailed and precise data than before can easily be obtained without staying always in the laboratory in order to operate the apparatus and to write down the data.

RESUMO

Um pêndulo de torção invertido do Centro de Metalurgia Nuclear do Instituto de Pesquisas Energéticas e Nucleares foi automatizado por meio de um sistema eletrônico de aquisição de dados marca Tectanel.

Este sistema permite a medição do atrito interno e do período de vibração em função da temperatura. Os dados obtidos foram analisados por um computador IBM/370/158 pertencente ao Centro de Processamento de Dados do IPEN.

ACKNOWLEDGEMENTS

The author is grateful to Prof. R. R. Pieroni and Dr. C. T. de Freitas for allowing him to do this project. All the members of the internal friction group of Centro de Metalurgia Nuclear are also acknowledged for their help during this work.

REFERENCES*

1. BATIST, R. de *Internal friction of structural defects in crystalline solids*. Amsterdam, North-Holland, 1972.
2. IWASAKI, K. *Bull. Japan Inst. Metals*, 15:43, 1976.
3. LIMA, L. F. C. P. de *Contribuição ao estudo dos defeitos produzidos por irradiação e por dopagem em monocristais de L.F.* São Paulo, 1975. (Dissertação mestrado. Universidade de São Paulo).
4. NOWICK, A. S. & BERRY, B. S. *Anelastic relaxation in crystalline solids*. New York, NY., Academic, 1972.
5. SUGIMOTO, K. *Bull. Japan Inst. Metals*, 14:491, 1975.

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