GRANITE SAMPLE AND ELECTRO-ULTRASONIC SPECTROSCOPY

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ABSTRACT

Electro-ultrasonic spectroscopy is based on interaction of two signals. Electric AC signal with frequency f_E and ultrasonic signal with frequency f_U. The ultrasonic signal changes the resistance ΔR of the measured sample by frequency of ultrasonic excitation f_U. Defects in the material are causes of larger resistance changes ΔR in comparison to a material without defects for the same amplitude of ultrasonic signal. We have tried applying electro-ultrasonic spectroscopy on rock sample of granite. The paper presents some results of this new method for the non-destructive testing of conducting and resistive material which was granite sample in our case. The non-linear electro-ultrasonic spectroscopy offers higher sensitivity and wider range of application than common ultrasonic testing method which has many problems.

1. INTRODUCTION

The ultrasonic is used for prediction of lifetime for any products in the non-destructive spectroscopy. This non-destructive testing method is not fit in case a sample has complicated form or a sample is made of non-homogenous materials.

Electro-ultrasonic spectroscopy is sensitive on defects and unhomogeneities in the material by intermodulating of ultrasonic signal and electric signal. The ultrasonic signal changes the contact area between conducting grains in the material structure. Then material resistivity is changing with frequency of ultrasonic excitation. Defects and un-homogeneities are described by the intermodulation signal on frequency f_m which is given by the superposition or subtraction of excited frequencies ultrasonic and electric signal. We have measured on low frequency where intermodulation signal is given $f_m = f_E - f_U$. Intermodulation signal frequency is not the same as frequency exciting signals so we can get extra high resolution susceptibility with appropriate electric filters [1].

An electric resistance of the granite sample is of the order of R = 10 MΩ. Since material has many unhomogeneities in the structure, we suppose high level of measured intermodulation signal on frequency f_m.

2. ELECTRO-ULTRASONIC MEASUREMENT SETUP

The block scheme of the electro-ultrasonic measurement setup is shown in Fig. 1. It consists of two parts, the electric and the ultrasonic ones.

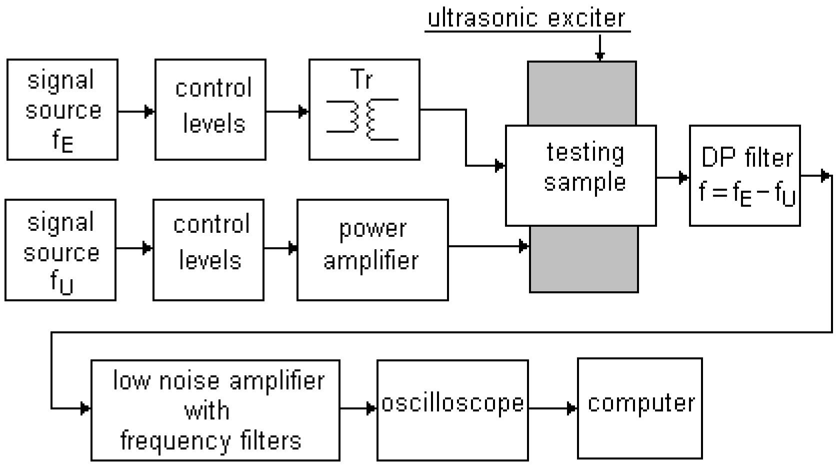

Fig. 1: Electro-ultrasonic measurement setup with AC electric signal.

The ultrasonic part contains a signal generator (Agilent), a power amplifier and piezoelectric transmitter (HTP04). Generator Agilent 33220A can be used in frequency range 1 µHz – 20 MHz for sine and rectangle functions. Maximum length of the programmed signal is 64.000 points and vertical resolution is 64 bits. The power amplifier is consists of WPD 100 in which it is necessary to have power linear actuating harmonic signal on ultrasonic transducer. The measured sample was fixed on the power piezoceramic transmitter (HTP04) which is used for ultrasonic signal generation.

Electric part is consists of generator Tesla BM492 which offers convenient linearity and frequency stability. Signal from the generator is transformed on higher voltage from transformer Tr. This signal is led to the measured sample over the protective resistor. Harmonic signals with frequency higher than the differential frequency component actuating signals are trimmed by the low pass passive filter. The passive filter has cut off frequency 4200 Hz with inhibition 50 dB / decade. The amplifier (AM 22) offers adjustable input gain in the range from -20 to 50 dB by 10 dB step, the frequency band filter with lower frequency 30 mHz, 300 mHz, 0.3 Hz, 3 Hz, 30 Hz, 300 Hz, 3 kHz, 30 kHz and 300 kHz, the high frequency filter adjustable in range 3 Hz, 30 Hz, 300 Hz, 3 kHz, 30 kHz and 300 kHz, adjustable output gain in range from 0 to 50 dB by 10 dB. All parameters can be set over GPIB or on the front panel of the amplifier. The amplified signal is led to the A/D converter. As the A/D converter is used digital oscilloscope Agilent 54624A with sampling rate 200 Msa / s. The digitized signal is stored in the computer and noise spectral density frequency dependence evaluated using discrete FFT. The control software was written in Borland C++ Builder and this version is based on Windows operating system. Amplifier AM22 and exciter HTP05 were produced by 3S Sedlak Company. Power amplifier WPD100 was made with help of Prof. K. Hajek.

3. MEASUREMENTS

We have measured on frequency of ultrasonic actuator f_U = 31.7 kHz. This frequency corresponds with resonant frequency of ultrasonic actuator. The frequency of the electric signal was f_E = 33.7 kHz so the intermodulation signal was on frequency f_m = 2 kHz. Gradually we increased the electric signal and the ultrasonic signal and searched the level of this intermodulation component on frequency f_m. Figure 2 represents measured the noise spectral density of the granite sample Z01. We can see the intermodulation signal on frequency 2 kHz and noise background decrease on frequency approximately 3 kHz which is given by the electric filters. Background noise is of the order of 10^{-13} V^2Hz^{-1}.

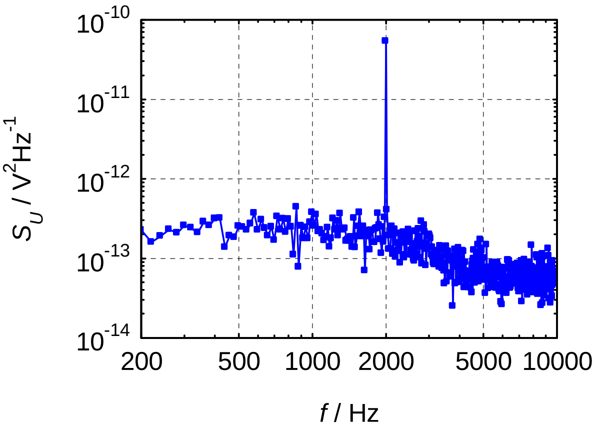

Fig. 2: Noise spectral density of granite sample Z01 in frequency range from 200 Hz to 10 kHz. Frequency f_E = 33.7 kHz and f_U = 31.7 kHz

The samples were measured with lower sapling rate, Fvz = 20 kHz. The voltage U_S on intermodulation frequency is given by equation (1)

$$U_m = \sqrt{S_u \cdot \Delta f} \tag{1}$$

where S_u *is the noise spectral density [* V^2Hz^{-1}*]*

Δf *is the distance between two successive lines in the signal spectra [Hz]*

4. RESULTS

The first measurement on the granite sample by electro-ultrasonic spectroscopy is presented. We are at the beginning of our research. We have tested the rock sample of granite denoted Z01. This sample had shape of prism 50 x 50 x 11 mm^3 (Fig. 3).

Fig. 3: The rock sample of granite. We can see electric contact on the sample fixed by DiAg paste

Electric contacts were fixed on the sample by dipping silver, how we can see in Fig 3. Sample was fixed on the ultrasonic transducer HTP05 by beeswax.

First we connected the ultrasonic transducer on the constant level for AC voltage with frequency f_U = 31.7 kHz. Electric AC signal with frequency f_E = 33.7 kHz and different level of amplitude U_E was led on the sample. We have measured intermodulation voltage on frequency f_m how we can see in Fig. 4. The intermodulation voltage U_m on the frequency f_m increases linearly with electric signal U_E.

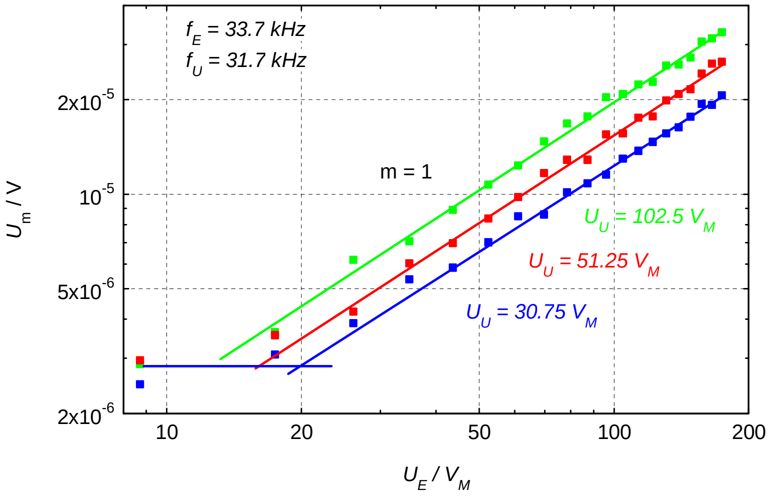

Fig. 4: The intermodulation voltage U_m vs. electric voltage for constant ultrasonic excitation U_U = 102.5, 51.25 and 30.75 V_M

On the second step we connected the sample on the AC voltage with the same frequency f_E = 33.7 kHz with constant level for amplitudes of electric signal. We have measured intermodulation voltage for different level of amplitudes of AC voltage led to the ultrasonic transducer with frequency f_U = 31.7 kHz. The intermodulation voltage U_m independent on the ultrasonic excitation for constant electric AC voltage is in Fig. 5. We can see that intermodulation voltage U_m is increasing with 0.7 power for ultrasonic excitation. The saturation of ultrasonic excitation appears for amplitudes U_U = 70 V and higher voltages led on the ultrasonic actuator.

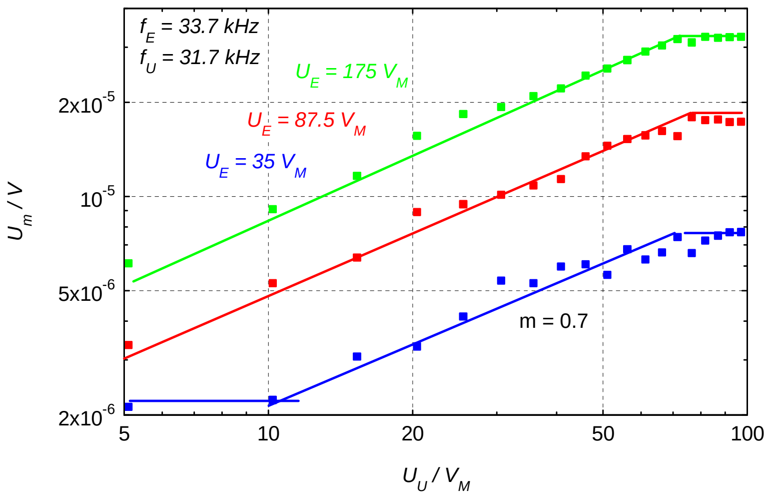

Fig. 5: The intermodulation voltage U_m vs. ultrasonic excitation for constant electric voltage U_E = 175, 87.5 and 35 V_M

5. CONCLUSION

We tested the rock sample of granite denoted Z01. This sample had shape of prism 50 x 50 x 11 mm^3.

The voltage U_m in dependence on ultrasonic excitation appears the saturation. The saturation of ultrasonic excitation occurs for ultrasonic voltage on sample Z01 U_U = 70 V for different constant electric voltage U_E = 175, 87.5 and 35 V_M, how it is shown in Fig. 5. The voltage U_m increases approximately with the 0.7 power of ultrasonic excitation for the granite sample Z01.

This method can be also used as a diagnostic tool for the quality and reliability assessment of resistors [2, 3, 4]. For given electric excitation the saturation occurs for the lower value U_U for the sample with lower reliability.

ACKNOWLEDGEMENTS

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