Interconnection between parameters of rock samples electromagnetic signals and content of magnetite in the samples

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Abstract. The paper describes the results of studies of electromagnetic response parameters of samples of bearing strata and ore rocks from the Tashtagol mine on acoustic effects. Patterns of changes in amplitude-frequency parameters of electromagnetic signals for rock samples with different content of magnetite are experimentally found. The conducted research shows that the maximum amplitudes of electromagnetic signal spectral components increases in samples of the same mineral composition with the reduction of their ultimate strength. This is caused by heterogeneities, and defective areas which contribute to active transformation of mechanical energy into electromagnetic energy. For rocks, which contain magnetite, the emissivity depends not only on heterogeneities and defective areas, but on the quantity of high-conductivity minerals in their composition.

1. Introduction

When developing the method to monitor changes in the stress-strain state of rocks and control bump hazard by characteristics of electromagnetic emission, knowledge of basic regularities in mechanoelectric transformations (MET) occurring in the array is required [1]. Physical modeling in laboratory and natural conditions is considered to be available [2-4]. Research of mechanisms of Ems and its sources in rocks at their straining and application of investigated parameters Ems for the control of destruction process also was spent in works of authors [5-16].

A fundamental property of the rocks is heterogeneity in structure, texture, composition and physico-mechanical properties. The author of the paper [17] divides the degree of heterogeneity into four groups:

1) large scale heterogeneity, including facies variation, tectonic breaks, the zone of weathering and unloading, technological heterogeneity;
2) heterogeneity of structure and composition of rocks within a single layer, including the fractured zone, presence of small tectonic dislocations);
3) heterogeneity of rocks within the elementary volume (sample), difference in chemical and mineral composition, shape and sizes of grains, cracks;
4) heterogeneity of real crystals, defects of the crystal lattice, and dislocations.

Thus, when studying rock samples, 3 and 4 groups are important factors of heterogeneity to be considered while analyzing the obtained results.

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The only fundamental force which integrates all the substances, including rocks, is the electromagnetic force. If mechanical stresses in the rock change, transformation of mechanical energy into electromagnetic one depends on petrographic and physical-and-mechanical properties of the interacting systems which carry energy. Real rock samples differ both in mineral and phase composition, the size and shape of grains, and in textures (pores, cracks and other stress raisers). Charged particles are more likely to accumulate on heterogeneities, electric field changes and, as a consequence, mechanical energy transforms into electromagnetic one [18]. MET causes generation of electromagnetic signals (EMS) by the rock which can be recordered with special instruments [19–20]. The method for monitoring changes in stress-strain state and forecasting rock burst being developed in Tomsk Polytechnic University (TPU) is based on the study of the properties and characteristics of MET.

In our earlier papers we presented the study of relation between parameters of electromagnetic signals and electrical properties of rocks under acoustic impact [21]. It is found that the amplitude of generated EMS depends on the conductivity of the rocks samples under study. In this regard, the task was to identify the dependence of EMS parameters on the amount of minerals with low electrical resistance in the rock.

2. Experimental technique and objects of research

Skarns of different petrographic composition containing no magnetite and ore with different content of magnetite from the Tashtagol iron-ore deposit were studied. The samples were cut from the core in the form of a cylinder (42 ± 1) mm in diameter and (80 ± 2) mm in height. The end faces of the samples were polished to make a parallel-sided sample with the discrepancy of (0.5 ± 0.1) and the axis of the sample and its ends were arranged under the angle of $(90 \pm 1)^o$.

The acoustic impact was made with a piezoelectric transformer (PET), by method developed in the Problem Research Laboratory of Electronics, Dielectrics and Semiconductors (PRL EDaS), Tomsk Polytechnic University (TPU) [22]. The duration of the acoustic signals to excite the sample changed discretely in the interval of 5 to 100 µs. The piezoelectric irradiator was excited by the electric pulse of a rectangular shape at a voltage of 800 V. The electromagnetic signals from rock samples were recorded with a digital storage oscilloscope Tektronix TDS2024B and transferred to a personal computer. Then, the amplitude-frequency spectra of EMS were calculated using fast Fourier and the data obtained were analyzed.

3. Experimental results

At the first stage of the experiments the amplitude-frequency parameters of the EMS for the samples with different content of magnetite were studied. Figure 1a shows a typical electromagnetic signal from a host rock sample under the duration of the PET electric excitation pulse of 10 µs. The amplitude-frequency spectrum of EMS is shown in figure 1b.

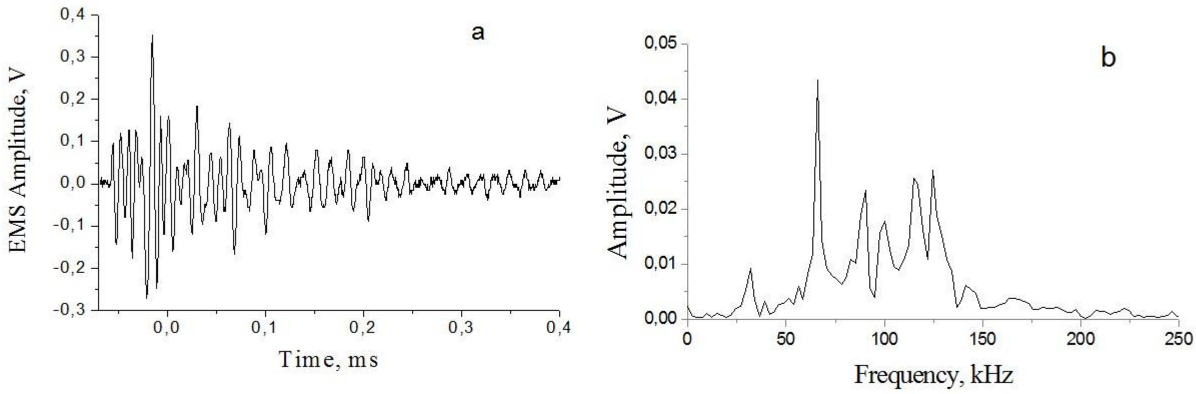

Figure 1. Electromagnetic signal (a) and its amplitude-frequency spectrum (b) in excitation by the acoustic pulse of 10 µs duration for bearing strata rock samples.

To simplify the analysis of the calculated spectra for each sample rock the frequency bands with the maximum amplitude values were determined. The obtained values were used to plot graphs for amplitudes of main spectral components of EMS (figures 2a,b). The figures show the graphs for samples from one group bearing strata rocks with different duration of the excitation pulse and different ultimate strength. Under uniaxial compression with the press (Testing Machine 500) the ultimate strength of the samples of bearing strata of rocks was defined:

- №0 is 188 kN;
- №4 is 320 kN;
- №3 is 234 kN.

Figure 2a shows that for the sample with the least value of the ultimate strength (sample №0) the maximum amplitude of EMS spectral components is observed under the excitation pulse of 5 μs. If the duration of the acoustic excitation pulse increases to 10 μs (figure 2b), the values of the maximum amplitudes of EMS decrease by 1 to 2 orders of magnitude if compared with acoustic excitation of 5 μs.

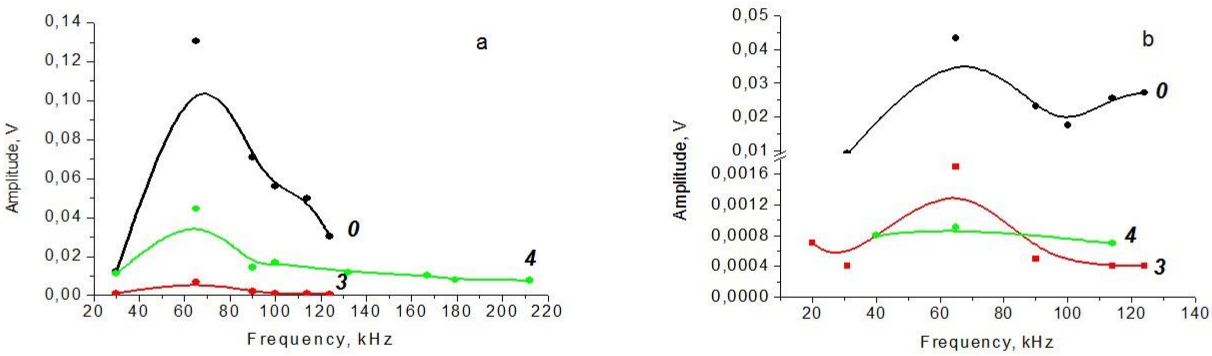

Figure 2. Graphs for the maximum amplitudes of EMS spectral components in excitation by the acoustic pulse of 5 μs (a) and 10 μs (b) for bearing strata rock samples.

Thus, it was experimentally found that as pulse duration of acoustic excitation increases from 5 to 10 μs, the maximum amplitude of EMS spectral components decreases. In samples of the same mineral composition decrease in their ultimate strength causes increase in the maximum amplitudes of EMS spectral components. This testifies to heterogeneities and defective areas that encourage active transformation of mechanical energy into electromagnetic energy due to increase in the number and extent of the charged electric double layers.

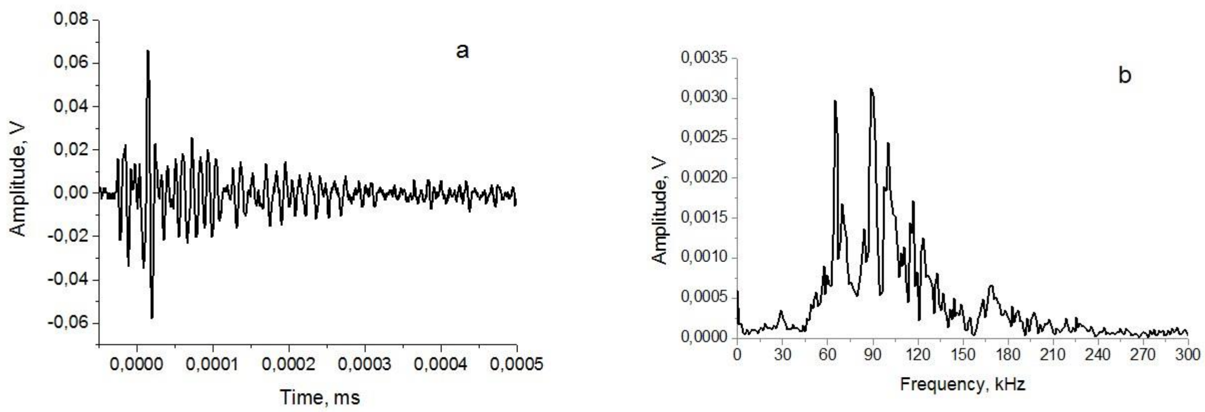

Figure 3. Electromagnetic signal (a) and its amplitude-frequency spectrum (b) in excitation by the acoustic pulse of 10 μs duration for ore samples.

The second group under study was ore samples with different content of magnetite. At the first stage, the ore samples as well as samples of bearing strata were excited by acoustic signals of 5 and 10 μs duration using the same acoustic transducer. Figure 3 shows a typical electromagnetic signal and the amplitude-frequency spectrum of one of the samples from this group.

The graphs with the maximum amplitudes of spectral components for this group of samples are presented in figure 4. The values of ultimate strength recorded under uniaxial compression for ore samples are 258 kN for №3, 317 kN for №4, 193 kN for №2, and 234 kN for №1. Figure 4 shows that the maximum amplitude of EMS spectral components in samples №3 and №4 are 2–3 orders of magnitude less than the amplitude of EMS in samples №1 and №2. These samples differ in their petrographic composition from the samples of the first group by magnetite content. Thus, the emission ability is affected not only by heterogeneities and defects of the composition, but the content of minerals with different electric and magnetic properties. It is known that the electric properties of rock samples depend on the electrical properties of minerals forming the rock. Therefore, they can change from sample to sample. For example, electrical resistivity (*p*) of bearing strata from the Tashtagol iron-ore deposit, presented by syenites, skarns of different composition, and diorites equals 10^3-10^6 Om•m. Electrical resistivity of magnetite mineral as a part of ores equals 10^{-2}-10^{-5} Om•m. Resistivity of the magnetite ore increases up to 10 Om•m due to inclusion of minerals with small value of ρ [23]. Thus, the more magnetite in the sample, the less its electrical resistivity, and therefore, emissivity of the rock decreases. The amount of magnetite affects emissive ability of ore samples. In our experiments the amount of magnetite in the samples was determined by weighing. It is known [24] that the specific gravity of magnetite is about 5 g/cm^3, for ore the proportion varies from 3.2 to 4.5 g/cm^3, hence, samples with a large amount of magnetite will have a higher weight. Considering that in our experiments, the volume of samples is equal, the specific gravity equals 3.8 g/cm^3 for №3, 3.7 g/cm^3 for №4, and 3.4 g/cm^3 for №2 and №1. Comparing the regularity presented in figure 4 and the calculated specific gravity of samples we can argue that the amount of high-conductive minerals affects the emission ability of the tested samples.

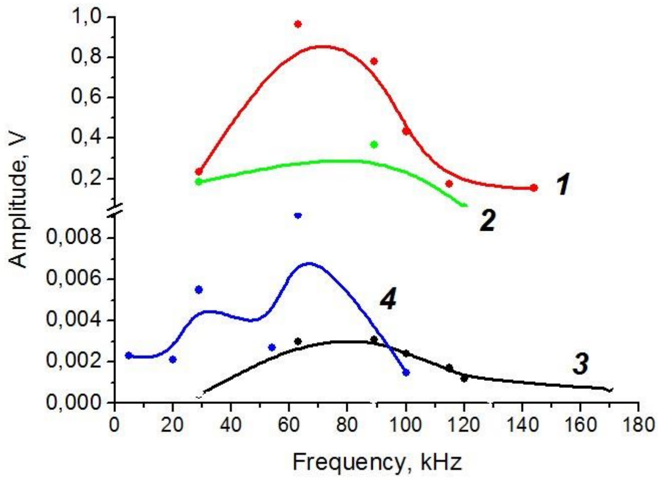

Figure 4. Dependences for the amplitude of EMS spectral components in excitation by the acoustic pulse of 10 μs duration for ore samples.

4. Conclusion

Thus, the conducted research of parameters of electromagnetic signals from the samples of bearing strata and ore rocks from the Tashtagol iron-ore deposit under acoustic excitation shows that in samples of equal mineral composition the maximum amplitudes of EMS spectral components increase if their ultimate strength decreases. This is caused by presence of heterogeneities and defective areas which contribute to active transformation of mechanical energy into electromagnetic energy. For rocks with high-conductivity minerals (such as magnetite) the emissivity depends not only on presence of heterogeneities and defective areas, but on the number of high-conductivity minerals as well.

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