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SPECTRA OF ACOUSTIC EMISSION INDUCED IN COAL BY GAS SORPTION

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ABSTRACT. Frequency spectra of acoustic emission (AE) induced in coal by gas sorption–desorption have been investigated in order to answer the following questions: Is there any difference between spectra of AE from coal prone and not prone to outbursts? Do spectra of AE signals indicate one or more source mechanisms? Changes in dominant frequencies of AE signals have been examined by means of statistical nonparametric methods: the Spearman's rank correlation, the Kolmogorov–Smirnov two sample test, the Wald–Wolfowitz runs test and the Mann–Withney U test.

These preliminary studies lead to the following conclusions:

- There are two distinct frequency modes: low frequency (LF) and high frequency (HF) corresponding to mechanisms which produce AE in coal under gas sorption–desorption process.The emission source mechanisms are not clear at this point.
- The dominant frequency distribution of AE signals from coal prone to outbursts significantly differs from that of not prone coal.
- Results of frequency domain AE analysis agree with conclusions arising from our earlier time domain studies.

The results obtained are encouraging from the standpoint of outbursts prediction.

1. INTRODUCTION

Outbursts have represented a serious problem at coal, potash and salt mines in Australia, Japan, China, the USA, Europe and the former USSR (1).

The outburst hazard in Poland is generally associated with coal. Considerable work has been done to characterize precursory phenomena which might provide warnings of imminent outbursts. However, most of the methods used to predict outbursts are not enough effective and credible. The same goes for AE techniques.

In our opinion efforts should be focused on the determination of the gas storage and flow characteristics of coal.

Permeability and sorptive properties of coal have been considered, in addition to gas pressure and stress, as the basic parameters which can have a bearing on outbursts.

Results of our previous investigations indicate that there is a relationship between observed AE and changes of coal permeability (2).

Experiments preceding the present study dealt with AE of coal subjected to CO_2 sorption–desorption process (3). Tests were conducted on two types of coal: prone and not prone to outbursts. The results obtained have shown that AE parameters in time domain provide a good measure of the proneness of coal to outbursts. Full details can be found in Majewska et al. (1994 a).

Unfortunately, our basic understanding of the origin of AE generated in coal by gas sorption is extremely limited due to the complex nature of interactions between gas molecules and the coal matrix.

With respect to clarify matters, frequency analysis of AE signals induced in coal by gas sorption has recently been undertaken by the present authors. There is a twofold reason for determining the frequency content of an individual AE event. The first one is for possible identification of source mechanisms. The second one is for recognizing differences between the AE generated during various stages of gas sorption–desorption process in two types of coal: prone and not prone to outburst.

2. Data analysis

Frequency analysis of AE signals induced in coal prone and not prone to outbursts under gas sorption and desorption was made using the FFT algorithm and nonparametric statistical methods.

At first, dominant frequencies of AE signals recorded during various stages of gas sorption – desorption process were determined. Data were divided into samples with regard to the type of coal tested and the kind of the process – either gas sorption or desorption. The sample sizes varied from intermediate to small (91 to 14).

All samples split clearly into two or in some cases into three frequency modes: low frequency LF – below 8000 Hz and high frequency HF – above 11000 to 13000 Hz. The intermediate mode was poorly represented. The division into modes was not unique. There were observations which could not be classified undoubtedly to one of modes and which outlied regardless of their classification. Distributions of dominant frequencies were not normal both in whole samples and in selected modes. Distributions of HF mode were usually less dispersed than those of LF mode.

Due to these specific sample features an application of parametric statistical methods was rejected.

We decided to investigate:

- time vs frequency relation in every sample with the use of the Spearman's rank correlation coefficient and the test of its significance.
- differences in dominant frequency distributions between selected data groups by means of the Kolmogorov – Smirnov two sample test. The analysis was made both in the full frequency range and in selected LF and HF bands.
- differences in the distribution of signal occurrence time between selected data groups by means of the Kolmogorov – Smirnov two sample test. The analysis was conducted in the full frequency range and also in selected LF and HF bands.
- differences in the central tendency of the dominant frequency distribution between selected data groups. The study was carried out in LF and HF bands

separately. Two procedures were tried for the purpose of this analysis: the Wald – Wolfowitz runs test and the Mann – Withney U test (known also as Mann – Withney – Wilcoxon test or the median U test). However, the Wald – Wolfowitz test was found to be unreliable for small size samples. Therefore, only results from the U test were taken into consideration. Note, that the U test is a robust test.

The Kruskal – Wallis ANOVA test was not used because it provides the same results as the median U test does in the case of simple models of interactions (it was the case of the present analysis).

- differences in the central tendency and in the distributions of AE signal occurrence time between LF and HF bands in each sample. The U median test and the Kolmogorov – Smirnov test were used for this purpose.

3. RESULTS AND DISCUSSION

Using the analytical techniques described several significant observations have been made.

In general, there are two distinct frequency modes: low frequency (LF) and high frequency (HF) probably corresponding to different mechanisms which produce AE in coal under gas sorption–desorption process (Fig.1,2).

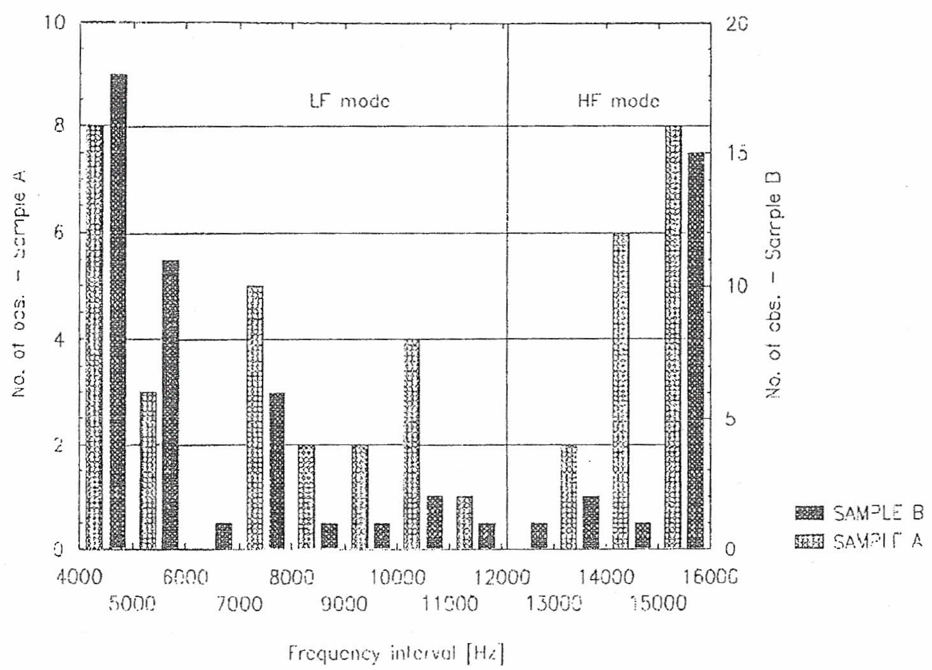

FIG 1. AE dominant frequency distribution during sorption

There is a tendency to lower the dominant frequency value of AE in the LF mode with the passage of time for both types of coal – prone and not prone to outbursts. It takes place as well during sorption and desorption . This shift towards lower frequencies may indicate an increase in the average source size in one type of AE mechanism.

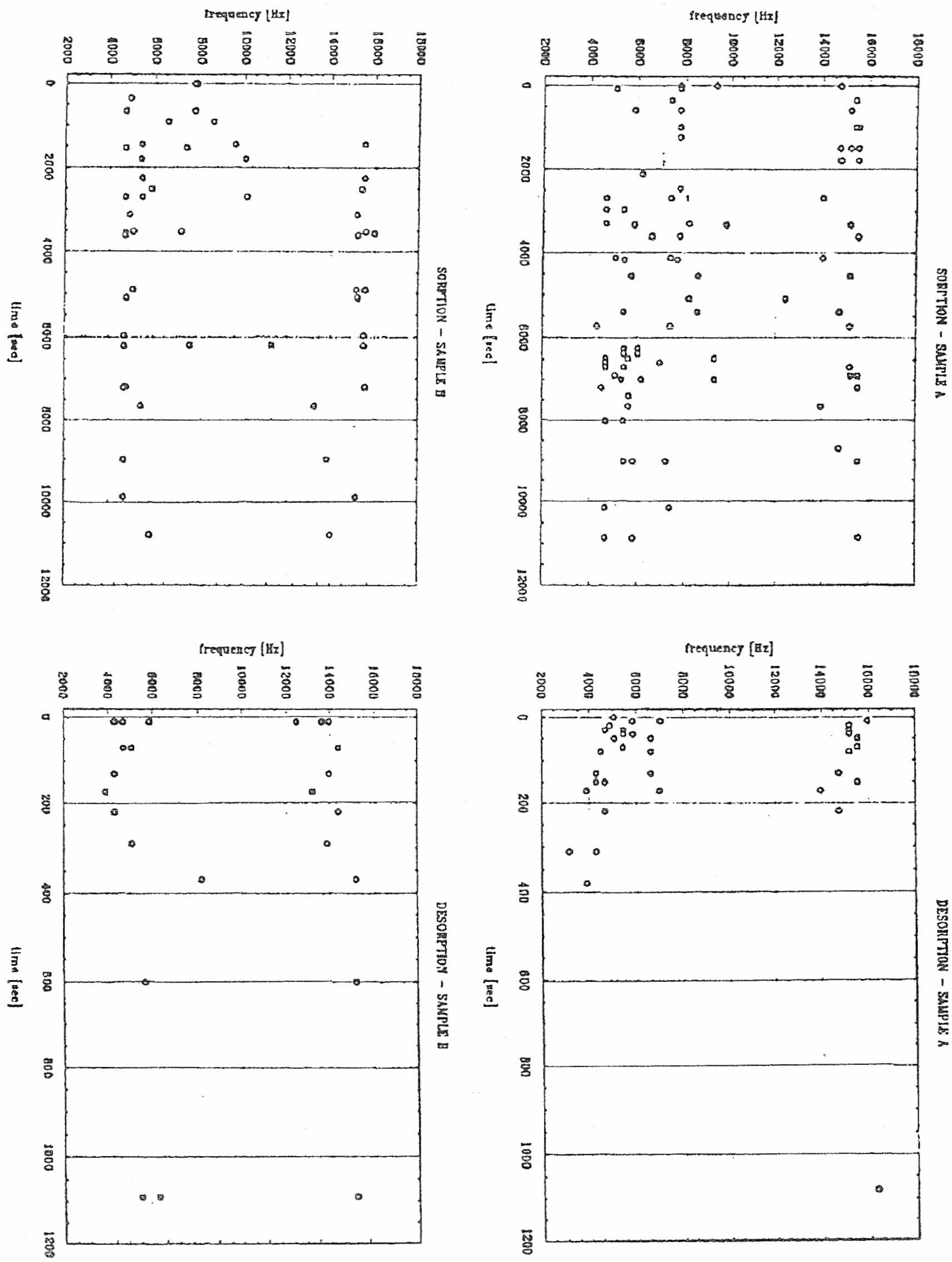

FIG. 2. Relation between the dominant frequency and time for coal prone (sample A) and not prone to outbursts (sample B).

The origin of AE induced in coal by gas sorption – desorption is not well understood, but recent studies gave substantial evidence that it is related to processes of deformation (4,5,6). In our opinion microfracturing constitutes only one of a number of processes responsible for AE.

Dominant frequencies of AE signals generated during CO_2 sorption – desorption in coal prone to outbursts are generally higher than those of not prone coal (Fig.1,2).

We do not know the precise reason for such behaviour, but we presume that the multifarious interactions between gas molecules and coal matrix can account for. As can be seen from Table 1 the two coal types discussed differ with respect to the volume of pores of various sizes.

TABLE 1. Pore volumes of coal tested (after Nodzeński, 1990)

Type of coal	V_{macro} [cm^3/g]	$V_{\text{macro}} + V_{\text{meso}}$ [cm^3/g]	$\frac{V_{\text{micro}} + V_{\text{meso}}}{V_{\text{macro}}}$
A	0.012	0.0664	5.5
B	0.0313	0.0236	0.75

It also appears from the analysis that AE signals exhibit statistically higher dominant frequencies during gas sorption than under desorption. Selected spectra are shown in figures 3 and 4.

It should be pointed out that investigations of AE spectra were limited to signals recorded in the narrow frequency band ($1 \div 20$ kHz). Therefore, results must be considered with caution, particularly in relation to possible source mechanisms of AE induced in coal by gas sorption – desorption. Additional work is needed in this area to clarify trends seen in the presented data set.

4. CONCLUSIONS

- There are two distinct frequency modes: low frequency (LF) and high frequency (HF) corresponding to mechanisms which produce AE in coal under gas sorption–desorption process.
- The emission source mechanisms are not clear at this point.
- The dominant frequency distribution of AE signals from coal prone to outbursts significantly differs from that of not prone coal.
- The results of frequency domain AE analysis agree with conclusions arising from our earlier time domain studies.

The results obtained are encouraging from the standpoint of outbursts prediction.

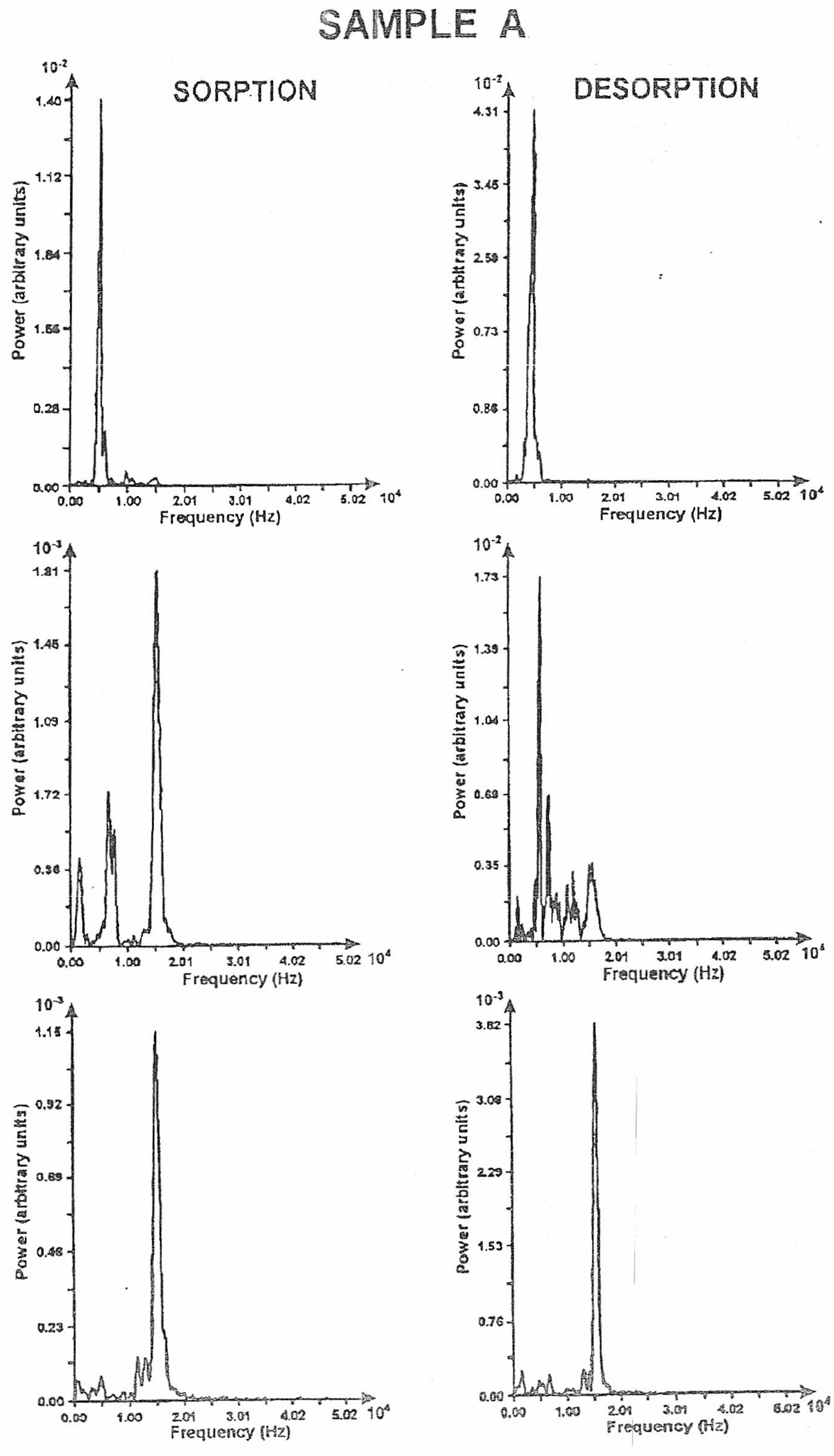

FIG. 3. Examples of AE spectra from coal prone to outbursts (Sample A)

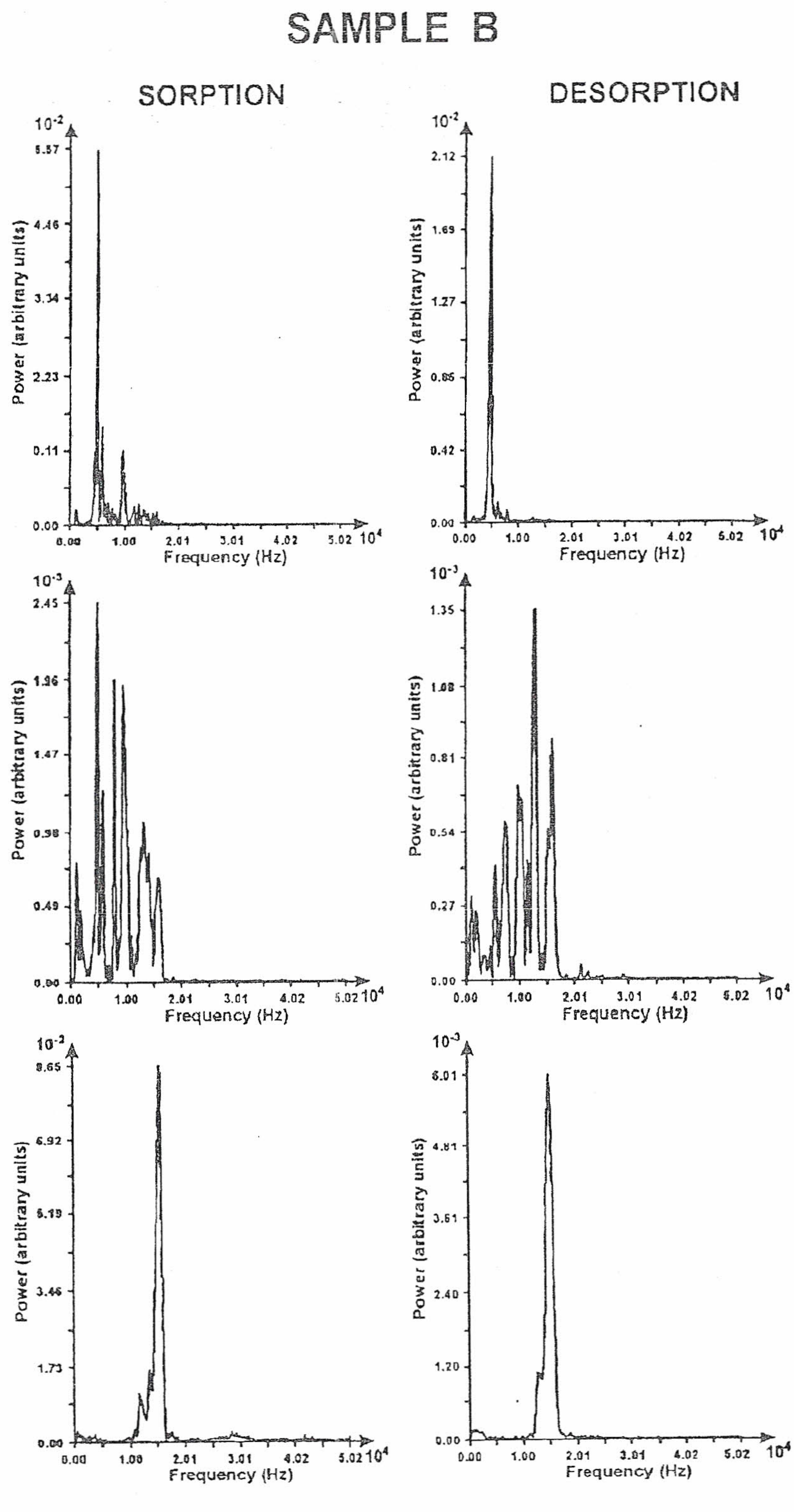

FIG. 4. Examples of AE spectra from coal prone to outbursts (Sample B)

REFERENCES

Jackson L. (1984), *Outbursts in Coal Mines*, Coal Research, Report No: CTIS/TR25.

Majewska Z., Marcak H. (1989), *The relationship between acoustic emission and permeability of rock under stress*, Mining Science and Technology 9, Amsterdam: Elsevier Science Publishers B.V, pp. 169–179.

Majewska Z., Majewski S., Mościcki W., Ziętek J. (1994a), *Acoustic Emission and Temperature Changes in Hard Coal during Carbon Dioxide Sorption – Desorption*, Rock Mechanics in Petroleum Engineering, Eurock'94, Delft, Netherlands, Proceedings SPE/ISRM International Conference, Balkema, Rotterdam, Brookfield, pp. 645–651.

Majewska Z., Majewski S., Marcak H., Mościcki W., Tomecka, Suchoń S., Ziętek J. (1994b), *Acoustic Emission of Coal Induced by Gas and Water Flow, Gas Sorption or Stress*, Journal of Acoustic Emission **12**, no. 3–4.

Czapliński A., Gustkiewicz J. (1990), *Sorption Stresses and Deformations in Coal*, In: J. Litwiniszyn (ed.), Strata as multiphase medium. Rock and gas outbursts. Vol.2, Cracow: AGH Publications, pp. 455–468.