STRUCTURAL NOISE
AS AN INFORMATIV PARAMETER
AT THE ULTRASONIC NONDESTRUCTIVE TESTING

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Self-descriptiveness of a structural noise of metal currently has not been studied enough. If a metal structure is an acoustic noise source, to obtain from it data re structural components is the task of proper interpretation and processing of an experimental results. As to a first approximation, average value of an amplitude of structural noise depends on the velocity of ultrasound longitudinal wave in metal and scattering coefficient.

Measurements were performed on a cast iron samples in a cubical form 100x100x100 mm and with various form of graphite: lamellar (#1), vermicular (#2), spheroidal (#3).

Fig. 1 Cast Iron Samples

Samples chemicals is shown in the Table 1. It can be considered constant for all samples.

Table 1

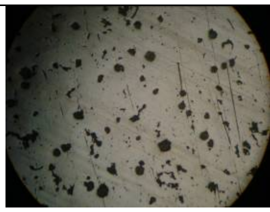
PERCENTAGE OF CHEMICAL ELEMENTS IN SAMPLES OF CAST IRON WIITH VARIOUS FORM OF GRAPHITE.

Chemical Element	C	Si	Mn	P,S	Mg
Sample №1	3,5-3,6	2,5-2,8	0,4-0,6	≤ 0,02	-
Sample №2	3,6	2,7	0,6	≤ 0,03	0,03
Sample №3	3,20-3,35	2,5-2,7	0,3-0,4	≤ 0,02	0,07

Metallogpaphic investigation of a structure and its description is provided in Table 2. Etching was performed with the HNO_3, concentration of 3%. Size and (30-60 mkm) and content (10-15%) of graphite engaging, and structures of metallic basis of samples almost don’t change. Thus, difference between samples is primarily in the form of graphite engaging.

Table 2.

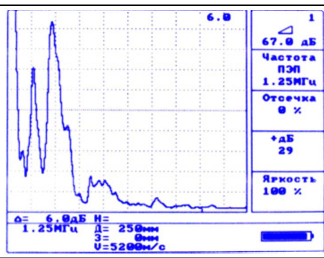
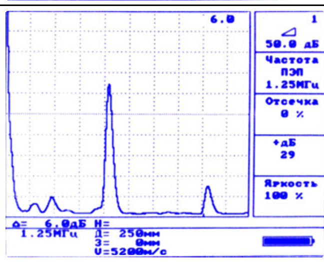
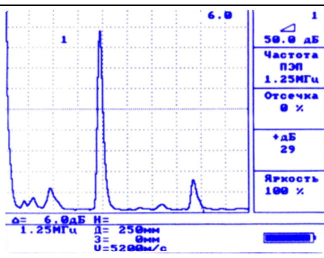
METALLOGRAPHIC STUDY OF SAMPLES

Sample No.	1	2	3
Photo of polished section , not etched, x 100			**Ошибка! Ошибка связи.**
Cast Iron structure description.	Lamellar graphite. Ferrite 20%, perlite 80%.	Vermicular graphite nestshaped. Ledeburite 20%, perlite 80%.	Spheroidal graphite. Ferrite 20-25%, perlite 80%.

Acoustic characteristics of cast iron comply with typical values for the provided structures, Table 3. Measurements were performed by means of fault finder УД2-70, echo-method, direct combined contact transformer with the frequency 1,25 MHz, plate diameter being 25 mm. Velocities of longitude wave and ratio signal/noise were measured.

Table 3

ACOUSTIC CHARACTERISTICS OF CAST IRON WITH VARIOUS GRAPHITE FORM

Acoustic Characteristics	Longitude supersonic wave velocity, km/sec	Ratio signal/noise	Defectogram
Sample №1	3,70	6	
Sample №2	4,41	20	
Sample №3	5,54	37	

Unfortunately, not all articles have two sided access. In case of molding thickness increase not always one can see the first base or even the transmitted acoustic signal on the background of the structural noise.

Large scale, complex configuration, specially processed surface – these are a few reasons, excluding possibility to use shadowy and echo-impulse methods of ultrasonic check.

One of the options in this situation is to use radio-engineering methods of separation of information on physics-mechanical characteristics and structure of cast iron from structural noise signal being registered.

Joint reflections of structure can be taken not as noise, but as information source on the article material structure. Whole of statistical timing and frequency data (Fourier spectrum of transformation and Gabor integral of transformation, weighted fixed instant spectrum) is offered to be used to define both combined and space local characteristics, and changes of echoic from the signal structure monitoring.

Three samples (shown at Fig.1) were studies. Ultrasonic firmware complex, manufactured on the basis of PC, equipped with analog-digital interface, was used for the study.

Studies were performed in two ranges – 600 kHz and 1000 kHz.

As a probing linear chirp was selected, its deviation frequency being 100% and base 200. After optimal filtering compressed echo-signal was mathematically processed, namely, inverse Fourier transform, integral Gabor transform and several original algorithms of normalization, weighing and accumulation.

Ground echo-signal on the sample of plexiglas, around 30 mm thick, was selected as a testing signal. Fig. 2 shows the results of the whole set of mathematical treatments application to the testing signal.

Fig. 2a shows the realization of testing echo-signals, Fig. 2b – its Fourier spectrum (Gabor transform), Fig. 2g – normalized instant spectrum, Fig. 2 d – suspended normalized instant spectrum, Fig. 2 e - projection graph of a counter spectrum of normalized Gabor transform to the frequencies axis, further as normalized amplitude spectrum.

Data obtained from the analysis of the normalized spectrum is the final target of our studies. This graph is similar to the Fig. 2b graph in many aspects, but is smoother, which allows with high reliability to evaluate numerically a ratio of frequency harmonics amplitudes of the registered signal spectrum. It has to be noted, that similar result could be achieved by stationaring at the accumulation with the averaging of several dozens of measurements of normalized amplitude Fourier spectrum.

Normalized amplitude spectrum of an echo-signal is similar to the linear chirp under the study, which means the presence of insignificant attenuation of the echo-signal at the sample thickness.

A fragment of normalized instant spectrum in the area of a second echo-signal (Fig. 2g) brings us to a conclusion that, first, primary weakening of components with high frequency of the spectrum is observed, due to presence of dispersion of frequency loss, and secondly, max of the spectrum has been shifted to the area of high frequencies, most likely, due to the opening angle of directional diagram with the frequency increase.

Figs. 3. 5. 7 show the study results of the cast iron sample of platelet, vermicular and spheroidal graphite in frequency range of 300-600 kHz. Comparative analysis of graphs (figs. 3t, 5e and 7e, accordingly) of normalized amplitude spectrum means that for each graphite form a certain graph type of certain amplitudes ratio is characteristic. Thus, for cast iron with spheroidal graphite the form of normalized amplitude spectrum practically repeats the form of a spectrum of a ground echo-signal of a testing sample, which means the insignificant echo-signal loss and practically complete absence of frequency dispersion of attenuation.

At the same time, for a cast iron with vermicular form of a graphite (see Fig.5e) normalized amplitude spectrum is practically same as spectrum (Fig. 7e) of global-shaped graphite, which brings us to the idea, that the computing spectrum correlates to ground signals to a greater extent, than signal of structural noise.

To check this hypothesis impulses of ground echo-signal of the first, second and third reflections were “cut out” from the registered realizations of echo-signals of structural noise of vermicular (Fig. 5a) and global-shaped cast iron (Fig. 7a). Lamellate cast iron the first ground echo-signal proved to be enough by the way of multiplying of the original realization to the weighting function of Gausian with appropriate timing delays (Figs. 4a, 6a, 8a, accordingly).

This iteration has brought expected result and put everything in proper places. Ratio of amplitude of local maximum in the range of frequencies of lower harmonic ($f_н \approx$ 300 KHz) and amplitude of local maximum in the range of medium harmonics frequencies ($f_0 \approx$ 600 KHz), which we called “Oktave Frequency Index of Cast Iron”, for spheroidal SOFICI = 1.25, for vermicular - VOFICI= 0.9, for lamellar - LOFICI = 0.7.

More of it, it has become evident, that the ground echo-signals presence produces negative effect on the reliability of the results of a comparative studies and during the analysis of experimental data ground echo-impulses should be excluded from the realizations of structural noise.

Similar studies were performed in the frequency range of 500 … 1000 kHz.

Experimentally computed indexes values were accordingly SOFICI = 1.15, VOFICI = 0.8, LOFICI = 0.65 .

Thus, one can say, that during preliminary tests, positive, practically, significant results were obtained. Mathematical algorithms were offered and new forms of structure scope information were defined.

It was shown by experimental way, that numeric value of octave-frequency index of cast iron is fixed by its structure. Further studies directions, in particular, will be linked to the analysis of this index value, defined for space-local fragments of realization of structural noise, corresponding to areas of the article under study, located at different depth.

It will let perform not only integral structure scope of cast iron articles, but to define space feature of distribution of various forms of graphite in the article under control.

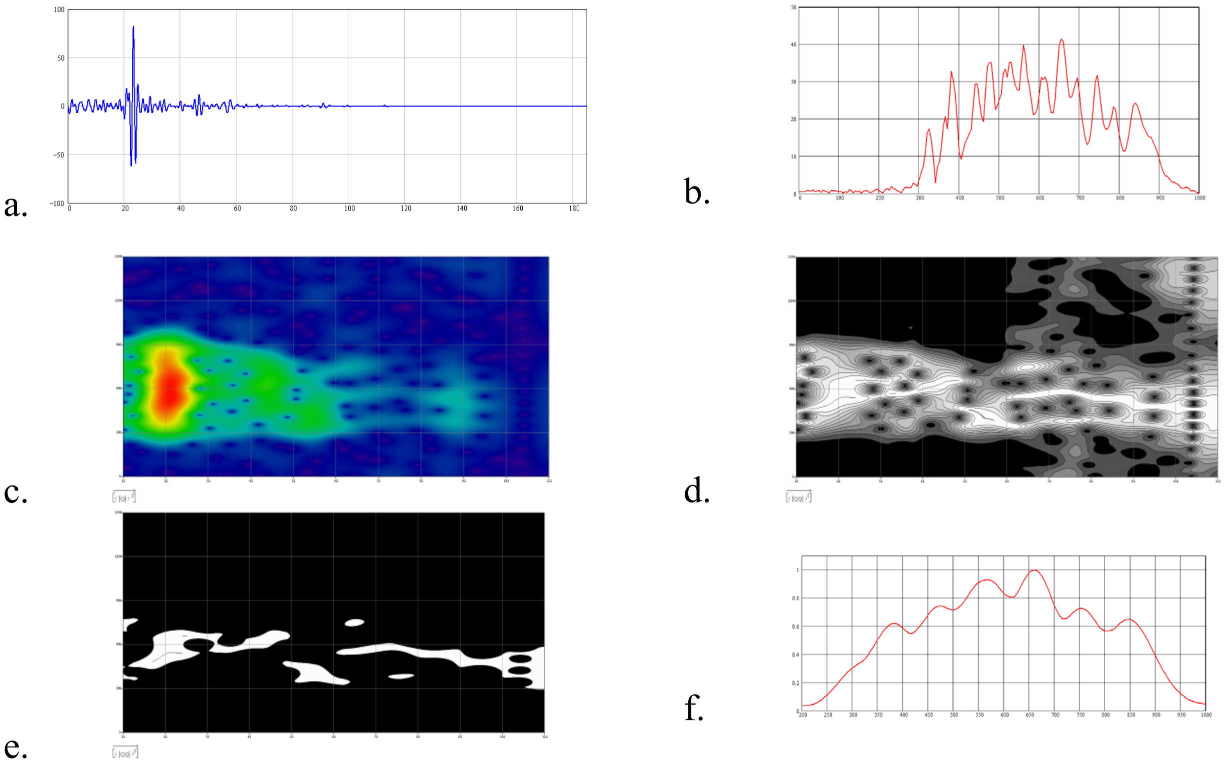


Fig. 2. Plexiglas, ultrasound frequency is 600 kHz; a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

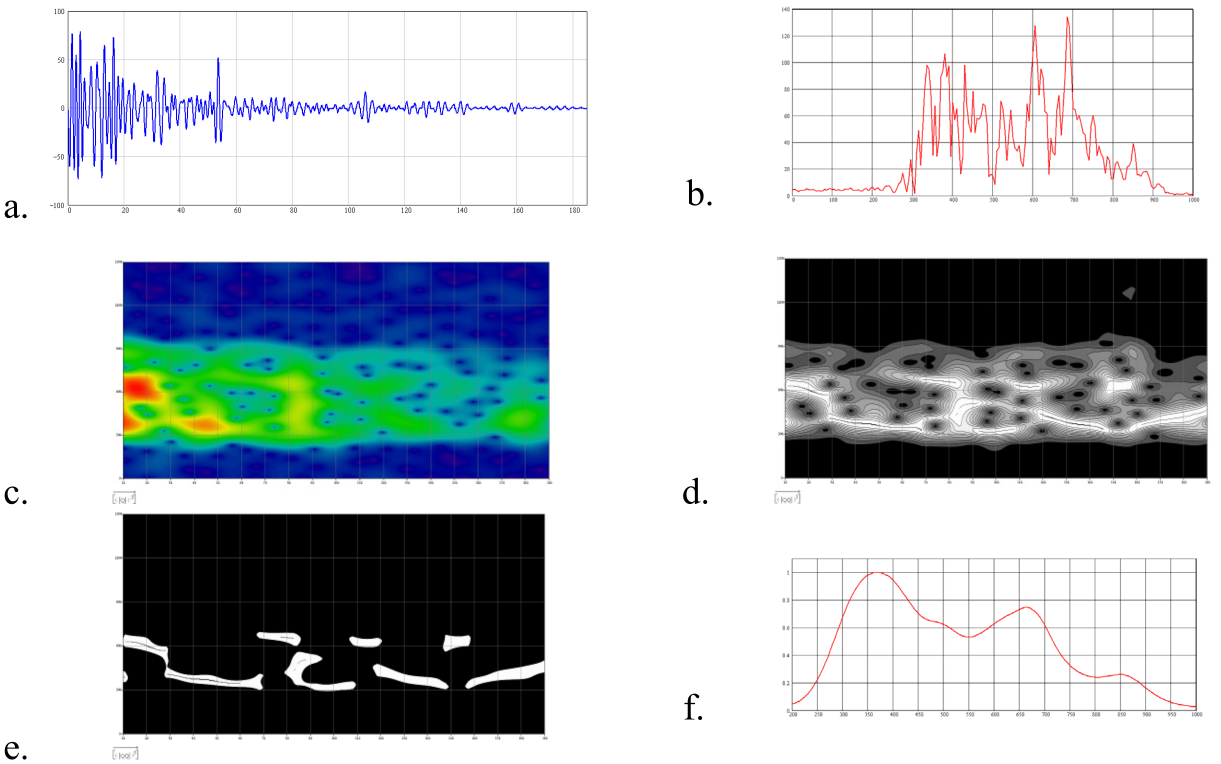


Fig. 3. Lamellar graphite, ultrasound frequency is 600 kHz (no compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

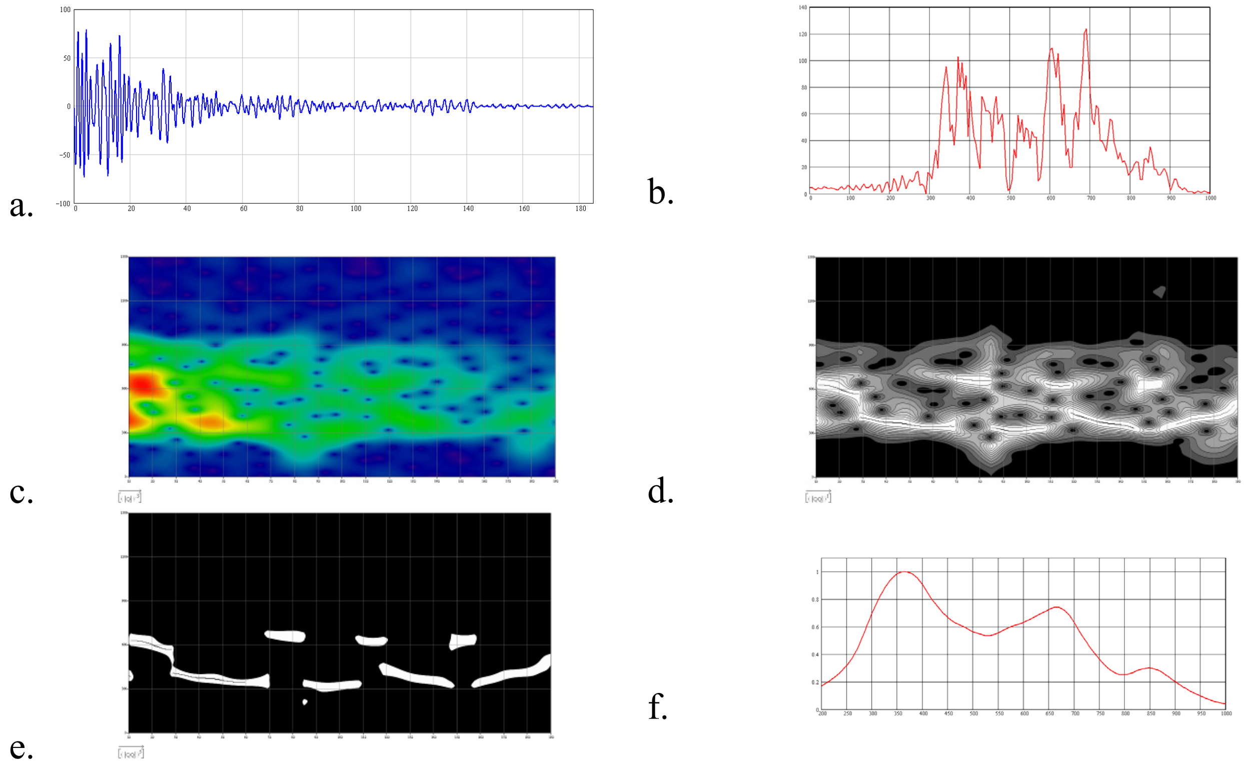


Fig. 4. Lamellar graphite, ultrasound frequency is 600 kHz (compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

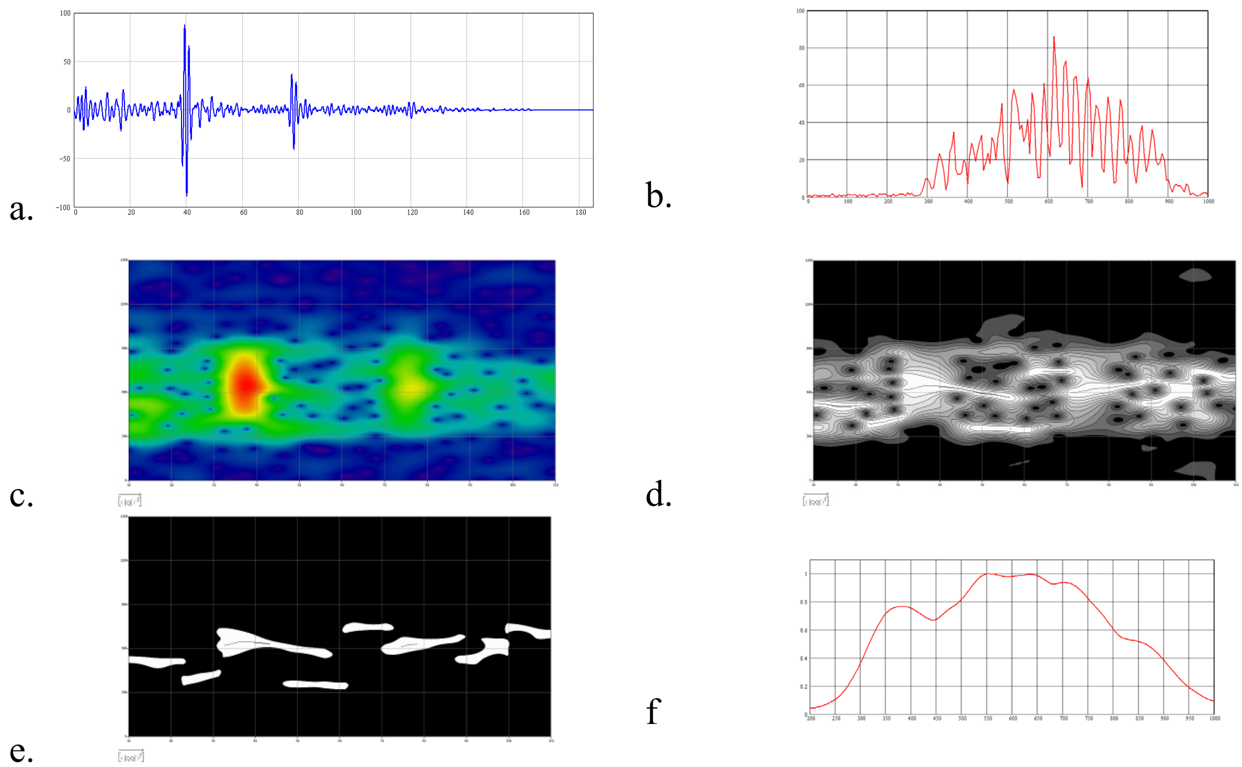


Fig. 5. Vermicular graphite, ultrasound frequency is 600 kHz (no compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

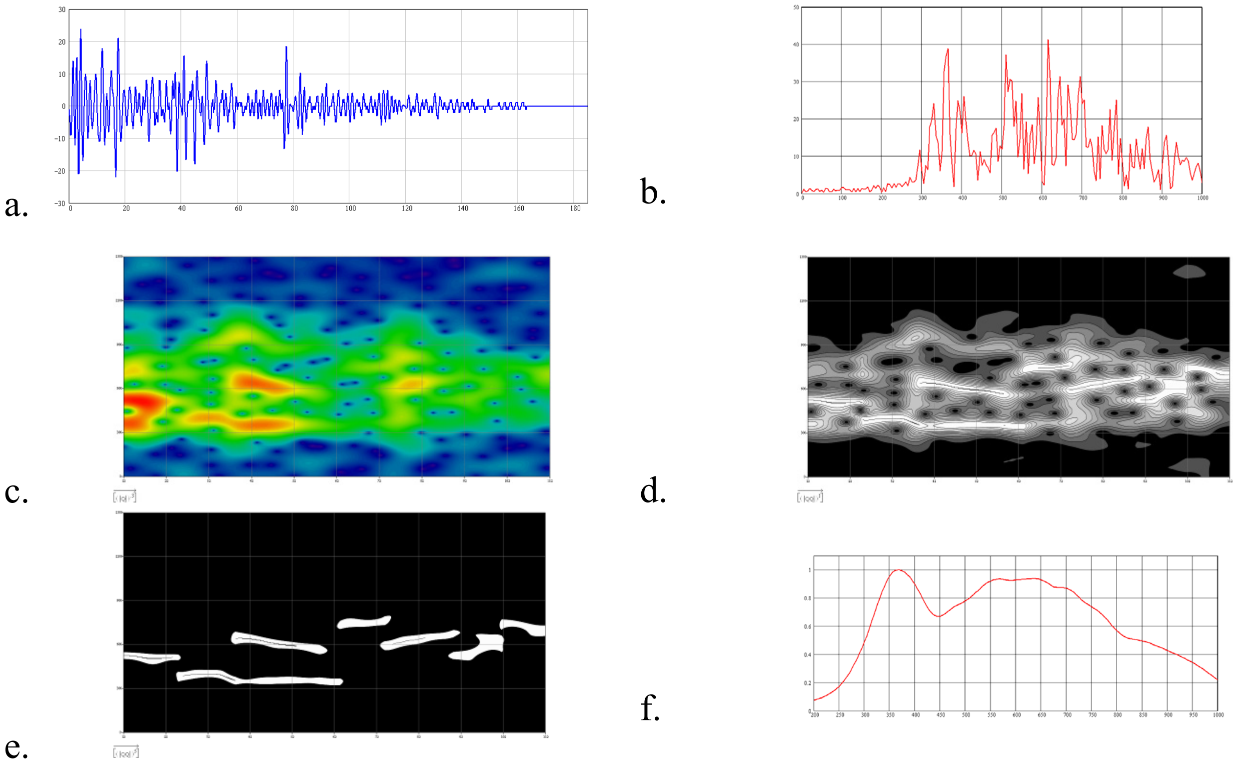


Fig.6. Vermicular graphite, ultrasound frequency is 600 kHz (compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum

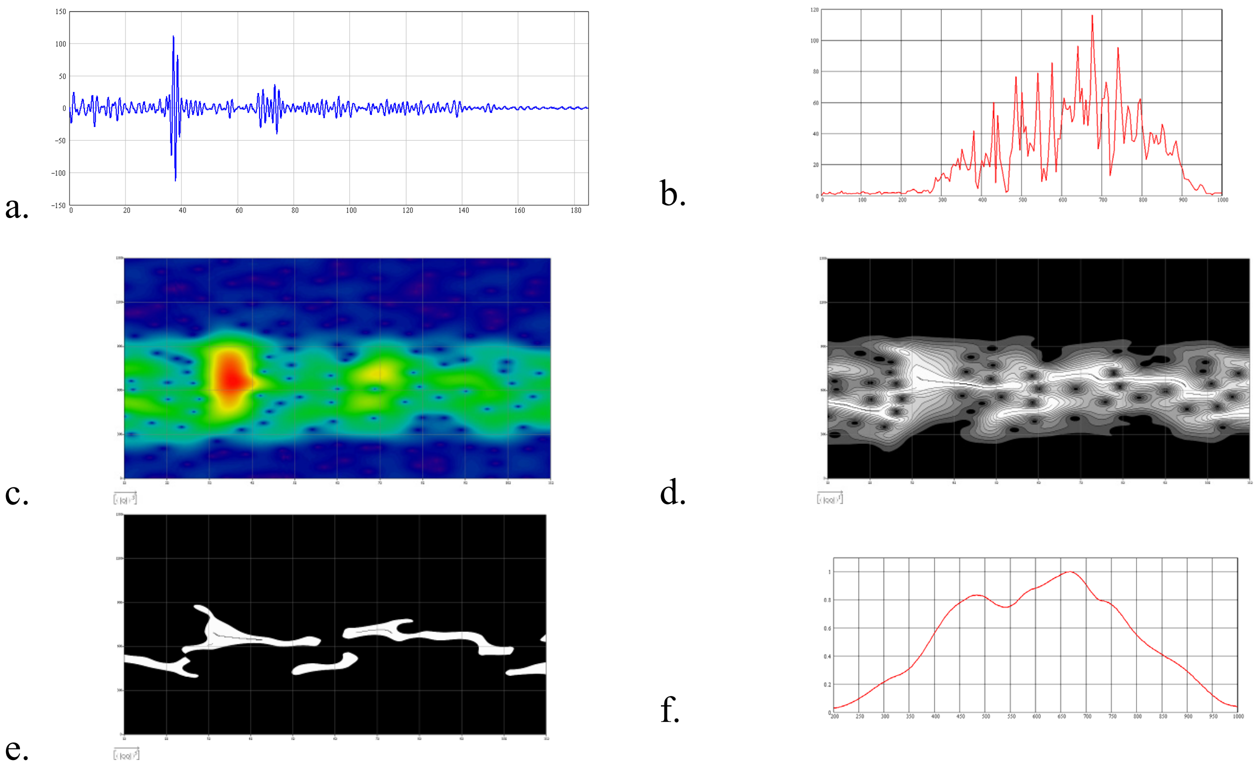


Fig.7. Spheroidal graphite, ultrasound frequency is 600 kHz (no compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

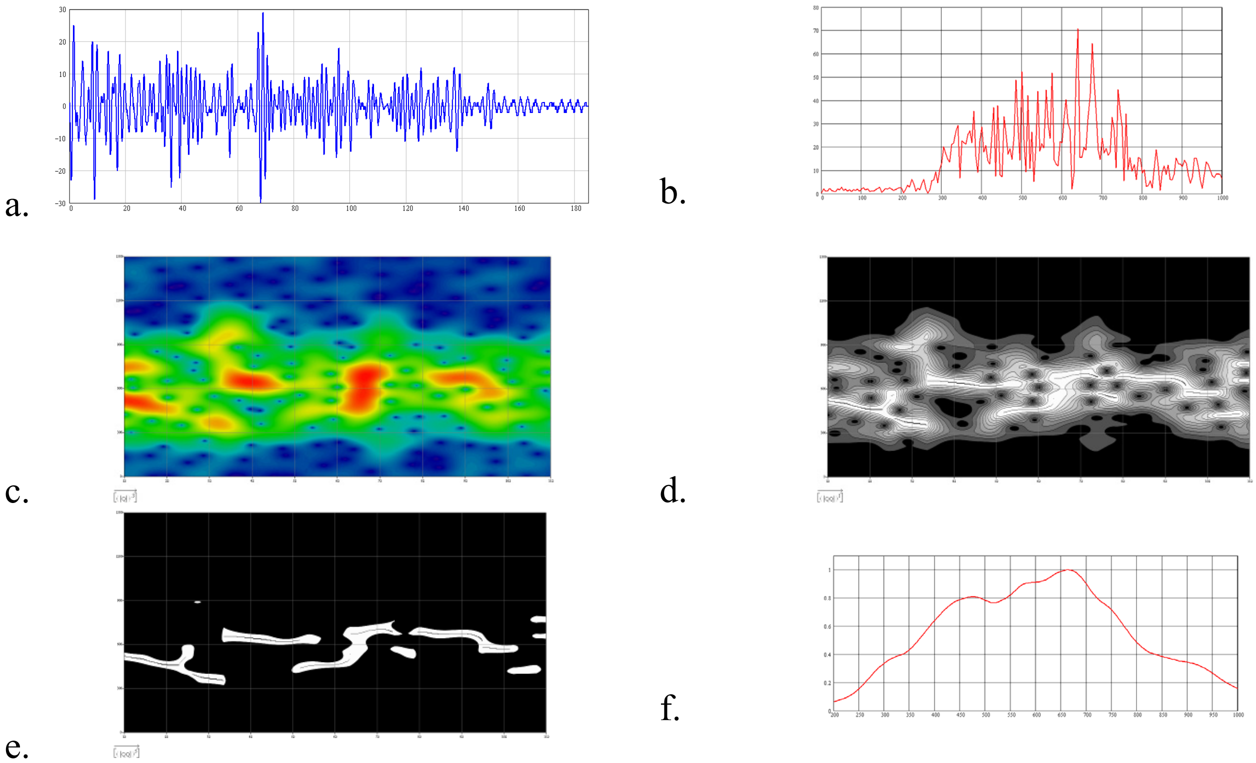


Fig.8. Spheroidal graphite, ultrasound frequency is 600 kHz (compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

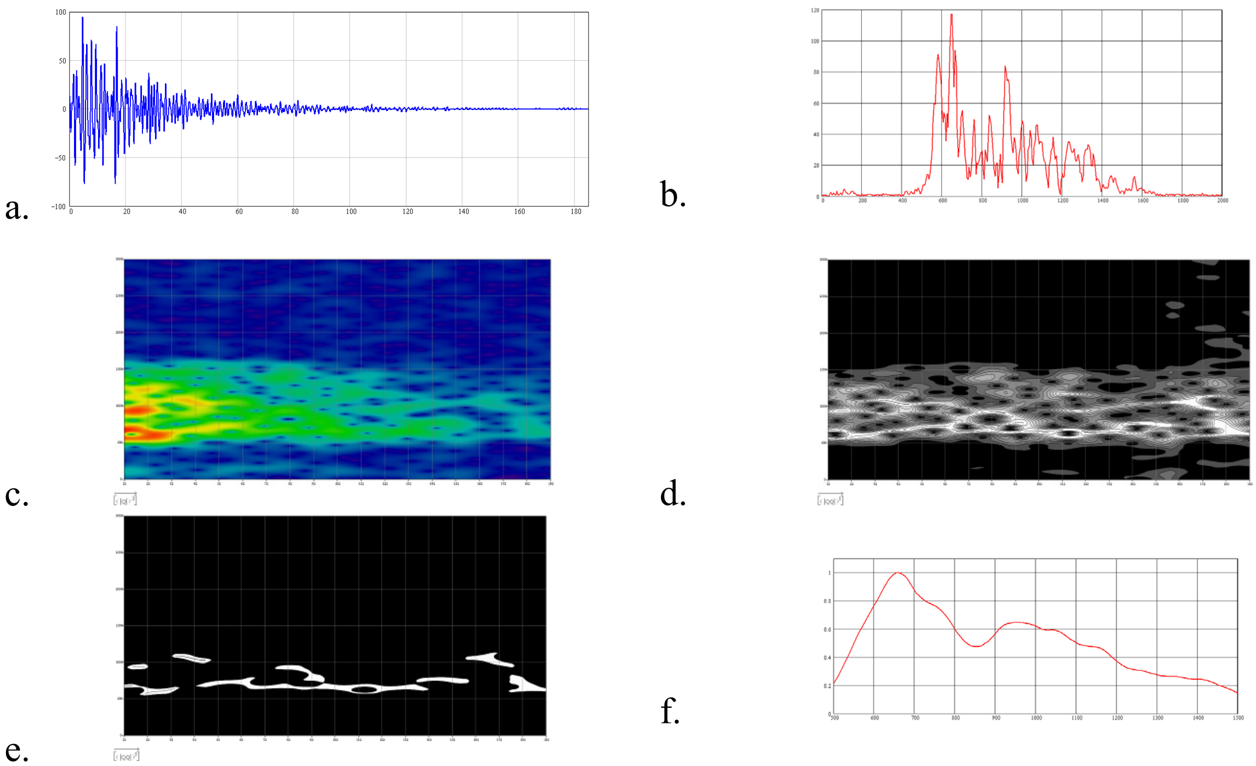


Fig.9. Lamellar graphite, ultrasound frequency is 1200 kHz: a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

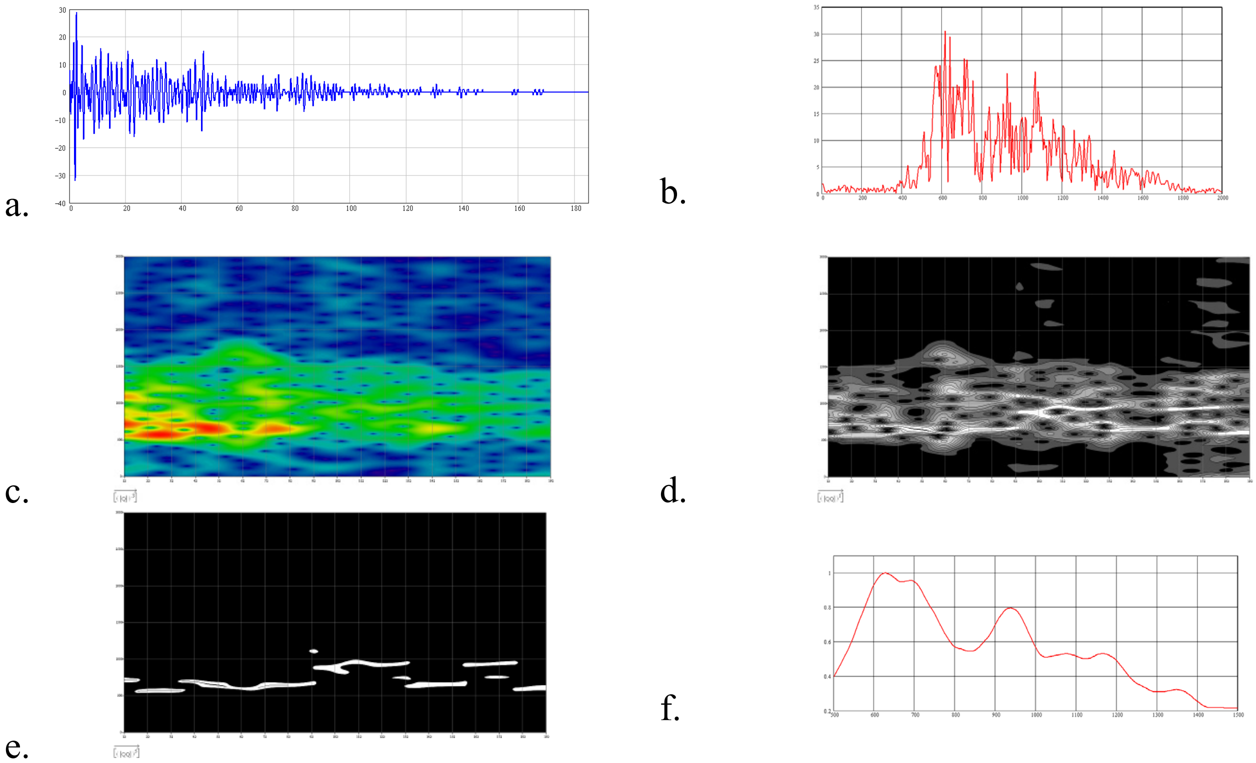


Fig.10. Vermicular graphite, ultrasound frequency is 600 kHz (compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.

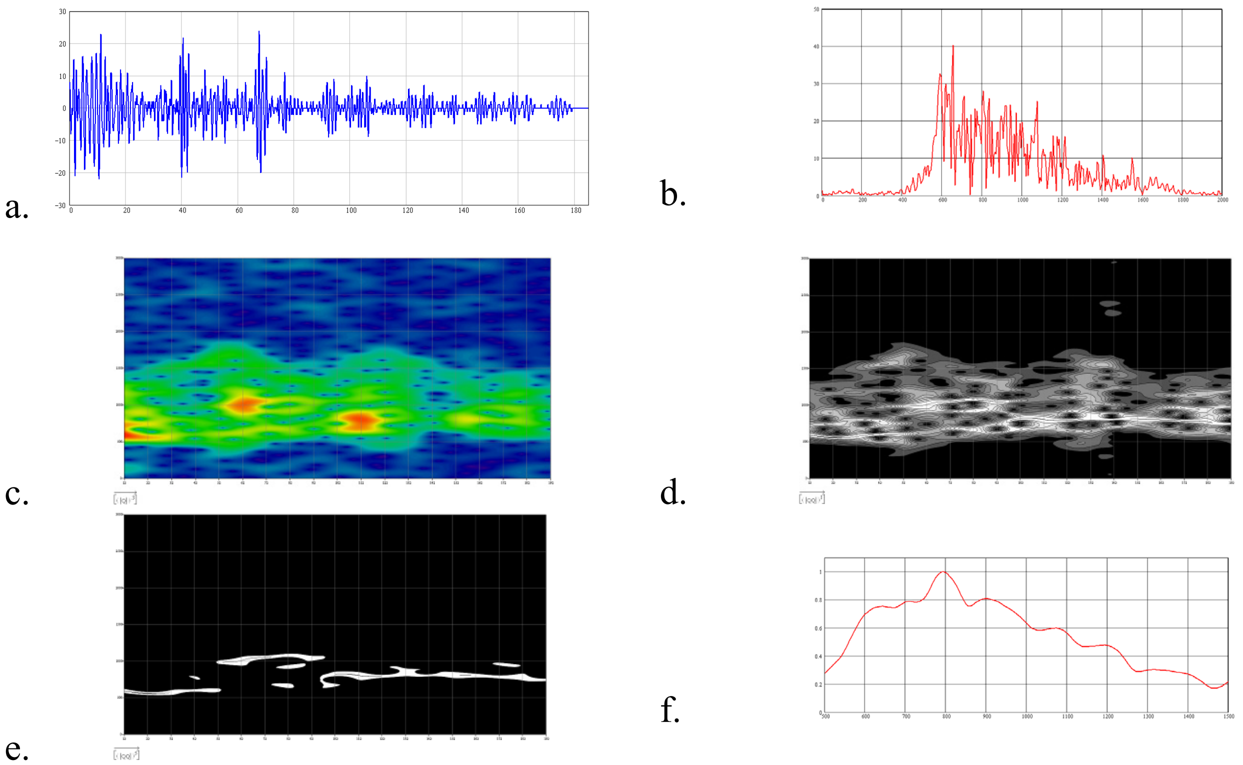


Fig.11. Spheroidal graphite, ultrasound frequency is 1200 kHz (compensation of a ground echo-signal); a). Echo-signal; b).Fourier echo-signal amplitude spectrum; c). Echo-signal instant spectrum (Gabor transfom); d). Normalized instant spectrum; e) Weighted normalized instant spectrum; f). Normalized amplitude spectrum.