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Acoustic Diagnosis Technique for Machine Condition Monitoring

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Abstract

This work presents a real time analyzer which allows extremely and accurately finding the noisiest of acoustic fluctuations in machines due to imposing spectra on the screen against each other. Technical and acoustic diagnostics of machines were predicted using the real time analyzer. The schemes and diagrams presented in this paper allow effectively using the studied real time analyzer for many other purposes.

Keywords: Analyzer; Real Time; Spectrum; Noise Meter; Filters.

1. Introduction

The development of modern machines is impossible without the constant control of its operation. Moreover, it is necessary to conduct an analysis of processes occurring in units of machines and also understanding the mechanisms and the performances of the previous generation of similar machines [1-3]. Most of the operations in the modern machines include acoustics and technical diagnostics which require the using of analyzers in real time [4 - 6].

Let's consider what opportunities open using a real time analyzer. For example, using of analog-digital correction and most applicable spectral analysis in 1/3 Octave band of frequencies. This spectrum meter can perform the automatic spectral analysis

in a range from 25 Hz up to 20 kHz with the help 30 Octave filters, and also if necessary under the characteristics A, B, C, D of noise meter [7-10]. The given device provides the analysis of a spectrum of signals and averaging of signals in time. The device can also estimate the maximal amount and record the received signals. Also, visual supervision on the indicator of a spectrum of signals and digital selective estimation in one of channels can be stipulated by the device. At a dynamic range of

60 dB, the resolving power of the device makes 0.2 dB. Exclusive accuracy of gauging thus is provided. In this work, the reliability and accuracy of the application of analyzer used for acoustic diagnostics was studied in more details and investigated.

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2. Analyzers Application for Acoustic Diagnostics

The acoustic analyzer is operating by receiving a signal from the converter (sensor placed on the examined object

or in the given point) which comes on broadband amplifiers (the preamplifier usually is on object together with the converter). Then the signal in each channel passes through the filter, square-law detector, amplifier and threshold circuit.

Circuits of averaging of memory and commutation further follow, then the signals come on the indicator on which for each analysis they are submitted as horizontal strips. The second channel begins from correcting filters (A- D) and gives integrated values which are mentioned before. In figure 1[2], the fields of the tolerance for one-third octave filters of the analyzer are presented.

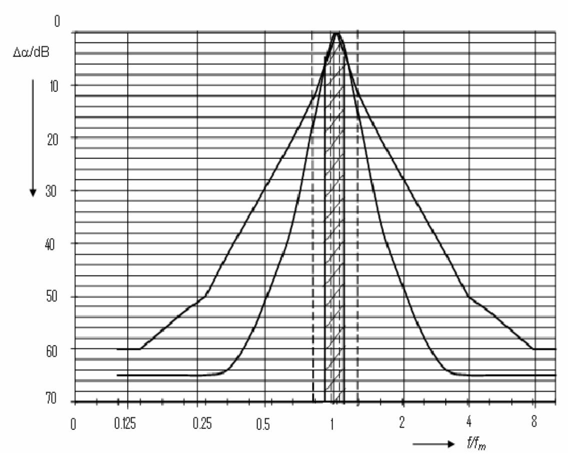

Figure. 1 Field of the tolerance for the relative characteristic of attenuation $\Delta\alpha$ for one -tried octave filters of rated frequency f / f_M and the relative characteristic of attenuation for channels of filters 25 Hz... 20 kHz of the analyzer of a spectrum [2].

In table 1, the correcting values of parameter of attenuation $f\,/\,f_M$ are shown. For the channels of filters, the field of the tolerance for the relative characteristic of attenuation Δα for one-third octave filters is valid. The image of the real characteristic of the attenuation of one-third octave filters for channels of 25 Hz …20 kHz was imposed on a field of the tolerance [11]. The curves are well coincide and as a whole are symmetric. The relative attenuation of 60 dB is already achieved at < 0.4 and > 2.5 $f\,/\,f_M$.

Table 1. Parameters of attenuation.

$f\,/\,f_M$	$\Delta\alpha$
≤ 0.1250	60 dB ≤ $\Delta\alpha$ < ∞
0.2500	50 dB ≤ $\Delta\alpha$ < ∞
0.7937	13 dB ≤ $\Delta\alpha$ < ∞
0.8909	-0.5 dB ≤ $\Delta\alpha$ ≤ 6dB
0.9439	-0.5 dB ≤ $\Delta\alpha$ ≤ 1dB
1.0000	-0.5 dB $\Delta\alpha$ = 0 dB
1.0595	-0.5 dB≤ $\Delta\alpha$ ≤ 1 dB
1.1225	-0.5 dB≤ $\Delta\alpha$ ≤ 6 dB
1.2599	13 dB ≤ $\Delta\alpha$ < ∞
4.0000	50 dB ≤ $\Delta\alpha$ < ∞
≥ 8.0000	60 dB ≤ $\Delta\alpha$ < ∞

Below 0.25 and above 4.0 $f\,/\,f_M$ there is a restriction of attenuation. In this case attenuation makes 62 ….66 dB depending on the channel of the filter. In the pass band no significant pulsation is observed.

Accordingly, the calibration on transfer factor of a microphone is applied, when its value is known, but the precondition is that this value remains constant. For test control and inspection measurements, the periodic control of microphones is necessary [12]. The calibration is based on basic sound pressure,

$P_0 = 2\cdot10^{-5}$ N/m^2 = $2\cdot10^{-5}$ Pa ≅ 0 dB

For microphones, the working sensitivity a_k and working factor of transfer B_k can be calculated using the following ratio:

$$a_k = 20\,\lg\left(\frac{B_K}{B_0}\right) dB \qquad (1)$$

Predetermined factor of transfer B_0 is accepted 10 mV/Pa. For capacitors measuring microphones, the values of the working factor of transfer is B_k and the working sensitivity a_k are:

for 1-inch microphone B_k ≈ 50 mV/Pa, a_k ≈ 14 dB

for 1/2-inch microphone B_k ≈ mV/Pa, a_k ≈ 0 dB

for 1/4-inch microphone B_k ≈ 2 mV/Pa, a_k ≈ -14 dB

For calibration of the inlet to the analyzer of a spectrum moves a calibrating voltage 100 mV and at the expense of change of amplifying and basic level of digital indication adjust the level of sound pressure, at which the microphone would produce a voltage of 100 mV. This calibrating level L_∇ makes for a microphone with working sensitivity a_k :

$$L_\nabla = 144\ dB - a_k \qquad (2)$$

For microphones with a_k = 14 dB levels of a voltage and sound pressure thus are simultaneously correctly shown.

Let p_∇ - sound pressure, at which the microphone produces a voltage of 100 mV, then, the calibrating level can be written as:

$$L_\nabla = 20\lg\frac{p_\nabla}{p_0} = 20\lg p_\nabla / Pa - \lg p_0 / Pa \quad \text{dB} \qquad (3)$$

The working sensitivity is determined as the 20-multiple logarithm of the relation between voltages which is raised at sound pressure p, to the agreed factor of transfer

10 mV/Pa. $a_k = 20\ \lg\dfrac{\frac{u}{p}}{\frac{10\ mV}{Pa}}$.

This implies: $\dfrac{a_k}{20} = \left(\lg\dfrac{u}{10mV} - \lg\dfrac{p}{Pa}\right)$

Further follows

$\lg\dfrac{p_0}{Pa} = \lg\ /2\cdot10^{-5}/ = -4{,}7$, *hence* $L_\nabla = 20/1 - \dfrac{a_k}{20dB} + 4{,}7$

dB, $L_\nabla = 114\ \ dB - a_k$

From the given below monogram (fig. 2), it is possible to take the calibrating level L_∇ , if the working factor of transfer B_k or working sensitivity a_k is known. Only for microphone cells the factor of transfer and amplifying are given at absence of load B_L by mV/Pa and dB accordingly,

$$a_L = 20\ \lg\left(\frac{B_L}{B_0}\right) \qquad (4)$$

For microphone preamplifiers the rate of attenuation a_V is shown, it is possible to find working factor of transfer: $a_k = a_L - a_V$.

The rate of attenuation a_V depends on the connected capacity of a source from given microphone cell. Rates a_V for average capacities of cells of various types (for example, a_V a= 68 for 1-inch cell) are therefore specified.

At the end, the analyzer allows, with the use of adjusting digital chain, effectively to accept a signal in a wide dynamic range of levels or voltage acting on the inlet of the amplifier, fig. 3.

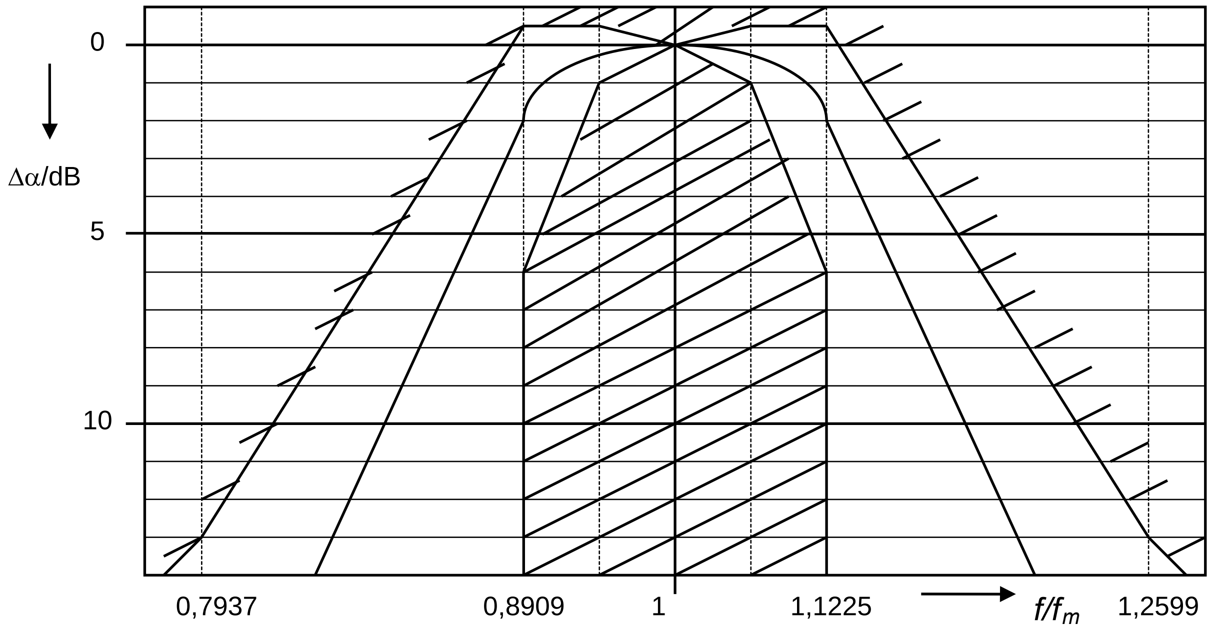

Figure 2. Fragment of figure with a site of the characteristic within a pass ban.

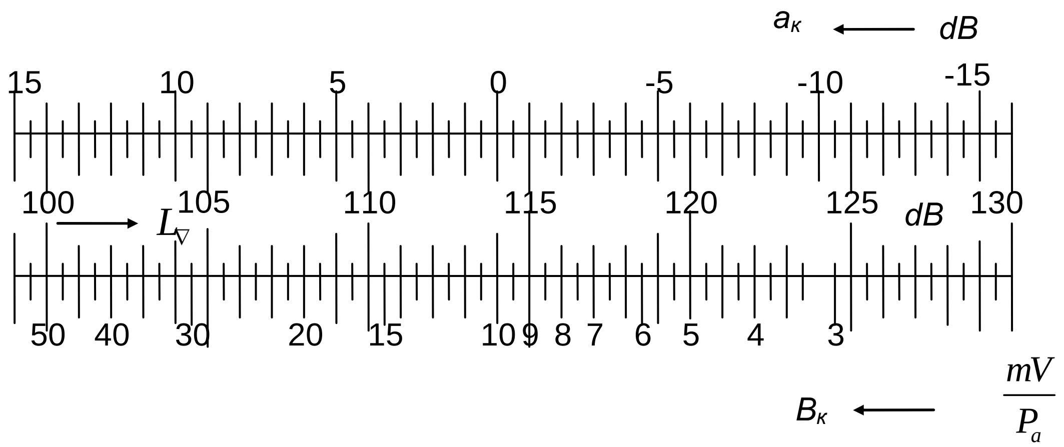

Figure 3. Monogram for finding L_∇ depending on B_k or a_k.

Thus, by using the developed measuring scheme it is possible, with practically complete technical reliability, to get spectra of levels of sound pressure in 1/3-octave bands of frequencies (octaves), for example, before and after covering of metal plates used for manufacturing of thin-walled protecting structures of the equipment.

Actually, the philosophy of measurement with the use of the analyzer and the measuring scheme consists of serial putting of damping coverings on the calibrated metal plates and measurement of acoustic efficiency of damping of a specific radiating surface.

To get the authentic results, the exact adjustment of a sound signal is important and its adequate presentation in an electrical signal with the subsequent giving to a scale of the meter (Fig. 4).

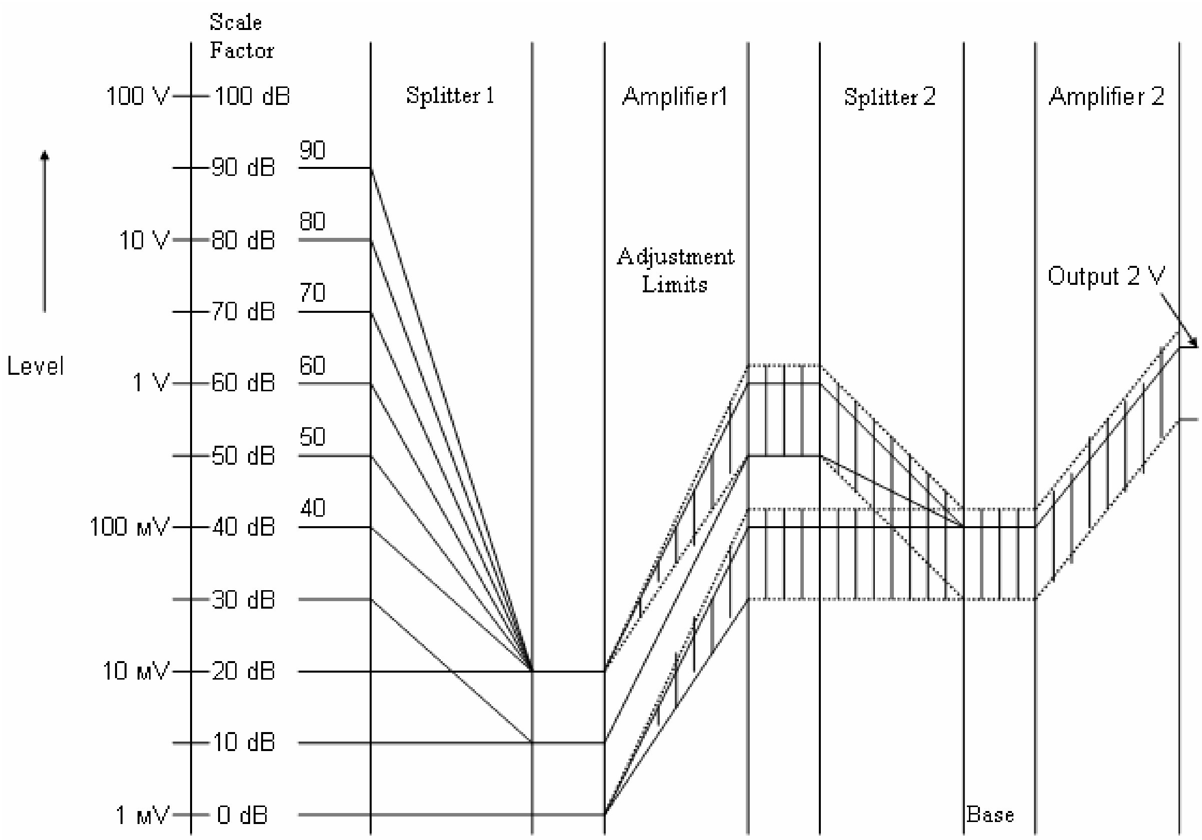

Figure 4. Diagram of a level of the Inlet amplifier.

3. Conclusion

The real time analyzer allows extremely authentically finding the noisiest source of acoustic fluctuations in the machine due to imposing spectra on the screen against each other. Separately there is a problem of technical and acoustic diagnostics of machines. The schemes and diagrams, submitted in this paper, allow effectively enough using the analyzer for many other purposes. The analyzer accepts a signal of a wide dynamic range of levels or voltage acting on the inlet of the amplifier. The rate of attenuation depends on the connected capacity of a source from a given microphone cell.

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