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THE STUDY OF THE DIAGNOSIS THEORY APPLIED FOR PREDICTIVE MAINTENANCE

STUDIUL TEORIEI DE DIAGNOSTICARE APLICATA PENTRU MENTENANTA PREDICTIVA

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Abstract: *This paper had as aim to present the actual stadium in the matter of diagnosis methods, processing methods of the signal, acoustic diagnosis, vibrational diagnosis and vibroacoustic diagnosis.*

Rezumat: *În această lucrare s-a urmărit prezentarea stadiului actual in ceea ce priveşte metodele de diagnosticare, metodele de prelucrare ale semnalului, diagnosticarea acustica, diagnosticarea vibrațională si diagnosticarea vibro-acustică.*

Key words: *diagnosis, noise, vibrations, maintenance, signal*
Cuvinte cheie: *diagnosticare, zgomot, vibrații, mentenață, semnal*

INTRODUCTION

Diagnosis and maintenance are two concepts that signify two different processes, but which are closely related one to another, the diagnosis results determining the actions which should be taken and its programming in the maintenance process. The diagnosis of an industrial machine designates the activities of data acquisition, processing and interpretation from the manufacture process which characterizes the functioning status of the respective machine. Maintenance represents all the operations where through the industrial equipments or machinery are maintained so that the equipments to function at optimal parameters, operations chosen after the interpretation of the signals acquisitioned during the manufacture process.

The application of diagnosis and maintenance in the manufacture process of a product, is imperious necessary as it is closely related to the product quality, characteristic that represented and will always represent a concern of the humanity. Walter Shewhart introduced in the period 1942-1943 the investigation methods using mathematical statistic for the control of the technological processes. There was a need of adequate tracing of the process to avoid the apparition of non-quality. Ulterior, in the period 1945-1950, it has been developed the reliability and on this occasion it has been proved that the conception phases of the product are decisive for its quality. The quality objective has evolved from a simple observation and selection of the inadequate elements, to the one of complete fulfil of all the beneficiaries requirements and expectations and also for the prevention of the defects occurrence. This presumed a movement of the concepts, organization and work methods, which are, in present, inconceivable without mathematical statistic. The quality of a product or a service is determined from all its creation phases: design, execution, delivery, exploitation. The concept becomes dynamic (evolves in time), relative (as a function of the beneficiary's needs and complex (is influenced by several independent activities).

The experimental method for the determination of the quality level of a technical product involves the evaluation of the technical characteristics, on the base of some tests, measurements, direct or indirect determinations. In order to have more relevant and concrete results for diagnosis there must be known more detailed: the work process of the industrial equipment; even to the level of compound, quality characteristics, vibrations sources and noise sources.

The quality characteristics are given in mainly from the technical characteristics. A machine tool is recognized in the processing precision of a piece by the technological precision, for which appreciation, the behaviour of the machine tool must be known, from the point of view: geometric, cinematic, static, dynamic and thermic. The dynamic phenomena which accompany the functioning of a machine tool have as mode of manifestation the vibrations, known as free vibrations, forced vibrations and self vibrations.

Free vibrations are described by the following information:

- Characterize the transitory process, its are of short duration (on-off, acceleration-brake of the mobile assembly, reversal of the direction of movement);
- Characterize the characteristic frequency of the elastic system;
- The study is made by the means of homogenous differential equations;
- The stability of the dynamic system can be appreciated from the solutions of differential equations which describes the transitory process.

Forced vibrations, in case of the machine tools, represent:

- vibrations which have as cause the variation of the processing additive, of the chip section, of the processing material hardness;
- vibrations that don't depend on the cutting process, having as causes the presence of the inertial forces, the vibrations transmitted from other machines;
- vibrations emerged at the concomitant action from several excitation factors of different natures;
- the vibrations amplitude depends on the parameters of the elastic system, but also depends on the frequency of the excitation force;
- the study of the forced vibrations allows the determination of the constructive parameters to avoid the apparition of the resonance.

Self vibrations are characterized by the following:

- are owed to different excitatory factors which don't have a periodical variation;
- the acknowledge of the laws which describe these vibrations is necessary for establishing the dynamic stability of the system;
- the vibrations amplitude varies function of cutting speed, feeding, and cutting depth.

Knowing the apparition causes and the existence of the vibrations conduce to a diagnosis more exact, giving the possibility of establishing the elimination measures or their diminution, which would reflect in the improvement of the quality performances of the machine tool. The main sources of noise from the machine tools are: bearing boxes, gears, electric motors for actuation and sometime even the cutting process.

DIAGNOSIS METHODS

At the base of electric signals processing stay different *signal models* and *processing methods*. From the processing methods we mention: statistic processing, classic Fourier transform (FFT), Fourier transform for short signals (JFFT), continuous wavelet transform (CWT; Haar wavelet, Morlet wavelet), algorithm for blind separation of the source (BSS), calculus method based on biological neural networks. For the statistic processing records we record on beside of using Kurtosis parameters (momentum of the 4 order), calculus method of the momentum of *n* order.

Signal models

- **Aleatory signals modulated in amplitude**

Mathematic expression of an aleatory signal modulated in amplitude is:

$X(t) = (1 + \gamma(t))\eta(t)$, where: $X(t)$ – measured signal; $\eta(t)$ – stationary aleatory signal; $\gamma(t)$ – modulation signal of low frequency.

The function *η(t)* is used to express high frequency wavelets, the process is not obligatory aleatory. The main condition is that the modulation signal *γ (t)* to be the same for all the possible compounds of the signal *X(t)*. In practice, the noise signals and vibrations measured contain components, including some very powerful, which either aren't modulated or have different rules for power fluctuation. In this case, in view of obtaining adequate results, it is extremely important to extract from the signal those components of which modulation must be investigated.

The spectral analysis of vibrations of high frequencies (noise) can be used to evaluate the parameters of the modulation function γ (t). In figure 1 there are presented examples of spectra for vibrations with high frequencies measured on rotative machines.

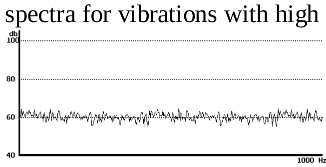


Fig. 1a. A component in good operation state (roller stadium bearing, fluid film bearing, pump, turbine) of the axle)

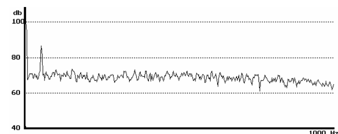


Fig. 1b. A component with defects in the incipient of development (good bearing with beats

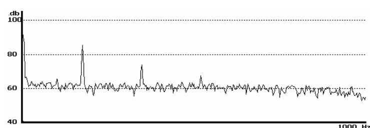


Fig. 1c. A roller bearing with significant wear of the friction surface from the exterior channel

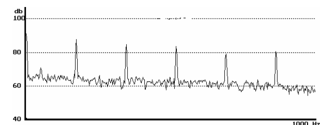


Fig. 1d. A roller bearing with well-developed cavity of the exterior channel

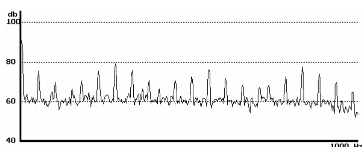


Fig. 1e. A roller bearing with deep cavity on the friction surface of the interior channel

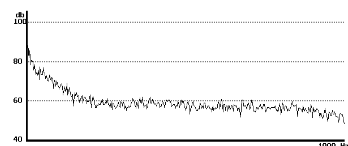


Fig. 1f. Defect components of the machine (fluid film bearing, pump, turbine) when the vibration of high frequency is modulated by an aleatory process of low frequency

The first spectrum of aleatory vibrations is typical for aleatory processes without fluctuations of low frequency of the power.

The second spectrum illustrates harmonic modulation of the power of high frequencies vibration of a machine. The power modulation index of the aleatory vibration defines the defect rigour. The third frequency spectrum was measured on the case of a bearing box with important wear for the friction surface of the exterior channel (stationary). The power modulation of the vibrations is also very smooth.

The fourth frequency spectrum was measured on a roller bearing (balls) with the exterior channel fissured, producing periodical shock impulses and of short duration.

The fifth frequency spectrum of the aleatory vibrations of a roller bearing illustrates a signal more complicated. Here the modulation function γ (t) is also modulated in amplitude.

The sixth frequency spectrum presents major differences from the anterior ones. This illustrates the case when the modulation process, γ (t), is itself aleatory, one of low frequency.

Signals modulated in frequency

Other practical case is constituted by the periodical signal with period fluctuations. In this case, the processes responsible for this kind of fluctuation may contain more components both periodical and aleatory. A model of such signal can be represented by the next equation:

$$X(t) = \sum_{k=-\infty}^{+\infty} A\{t - kT[1 + \infty]\}$$, where:

A(t) = a component of a singular signal, T = medium period of the signal, $\gamma(t)$ = modulation process.

The pulse electromagnetic twisting moment is a typical reason of the apparition of frequency modulation – in the vibration of electrical machines. As a rule, at the electrical machines without defects there is no twisting moment, this appears along with the electromagnetic system defects of the machines. The detection of the modulation function $\gamma(t)$ in the signal modulated in frequency can be done by the interpretation of the wavelet fronts in the periodical signal *A(t)*.

The model of modulated vibration can also be used to the diagnosis of the cylinder-piston assembly in the reciprocated machines. Taking into account that the shock impulses produced in the moment of the ignition of the combustible and changing of the movement direction of the piston can be easy detected in the vibrations background, the extraction of the modulation function $\gamma(t)$ can be done by the analysis of the increasing front of the shock impulses. Forwards the spectral analysis of this function and aleatory vibrations, if is necessary, allows the diagnosis also of the ignition system and the wear degree of the piston-cylinder assembly. The figure 2 contains an example of vibration of high frequency of a roller bearing, produced by shock impulses. There are presented the shape of amplitude - time wave of the vibration and the shocks distribution and its periods.

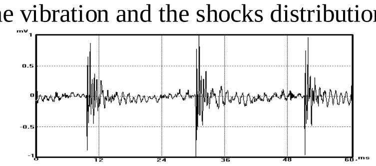


Fig. 2a. Wave shape in time of a roller bearing with deposits in the exterior channel

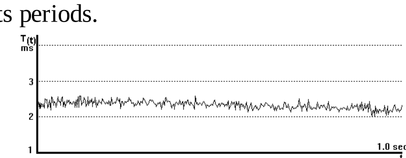


Fig. 2b. The time intervals distribution between the shock impulses in a roller bearing with deposit in the exterior channel during the initial stadium of the defect development

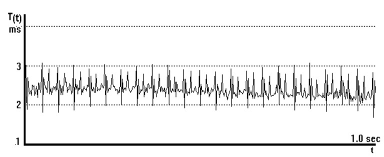


Fig. 2c. The time intervals distribution between the shock impulses in a roller bearing with deposit in the exterior channel in presence of a severe wear of the bearing box case

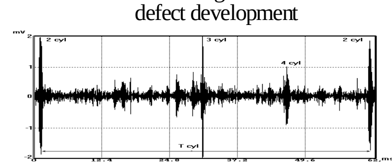


Fig. 2d. The wave shape in time of the vibration of an automobile engine

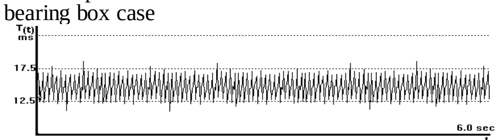


Fig. 2e. The time intervals distributions between the shock impulses in an automobile engine in case of failure at the ignition system

Other non-linear models of signal

Until recently, only the simplest non-linear models have found application in the practical diagnosis by vibrations and noises of the machines.

Those most simple types are: periodical signal modulated in amplitude by other periodical process, aleatory signals modulated by periodical process of low frequency and periodical signal modulated in frequency by a process of low frequency with periodical and aleatory components. Other non-linear simple model is the signal limited by amplitude or the duration that could be used, for example for the detection and identification of the magnetic saturation of the core in electric machines.

Other non-linear model is the one defined as pseudo-vibrations, the signals which are the results of the transducers effects. The estimation of the pseudo-vibrations in the global level of aleatory vibrations in the measurement points allows founding the points with maximum levels of pseudo-vibrations and the definition of its level, which permits the estimation of other parameters from the signals level of pseudo-vibrations. This method can be used, for example to find the place and the wear degree of the interior surface of a pump or pipe by the vibration of the exterior surface.

Processing methods of the signals for diagnosis

Statistic processing

The statistic processing of the noise and vibration signals, recorded in the monitor (control) process of a machine, is a method of primary processing, indicating the global state of functioning of the respective machine, without being able to indicate with precision which component is defected. The calculated parameters can be classified, from the point of view of their complexity, into classical (as: medium value, RMS value, PEAK value, standard deviation) and sophisticated (as kurtosis, bi-coherent deterioration factor at impact, asymmetry)

Harmonic wavelet transforms

Because of the complex nature and the great variety of machines utilised in the fabrication system is generally difficult or impossible to evaluate the state a machine directly from the un-processed vibration signal. The extraction of the characteristics and selection techniques must be utilised to identify the apparition of the new characteristics and typologies (signatures) of signals that indicates the changing of state of the machine which is monitored.

The technique of the common spectral analysis as ***FFT (Fast Fourier Transform*)** is based on the presumption that the signals are stationary and it is not adequate for non-stationary or transitory signals analysis, typical to machines vibrations. ***WT (wavelet transform)***, which can be seen as an extension of the conventional spectral technique with a size of the adjustable window, it has been revealed as an alternative tool for the characteristics extraction (parameters).

The signal is disassembled in 4 groups by disassembling the wavelet on tree levels: a group for *approximate* information and 3 groups for *detailed* information. *Approximation* group corresponds to the inferior eight of the frequency region of frequency of the signal, whilst the detailed group covers the rest of the regions. ***Wave Package Transform (WPT)***, by comparison, decomposes farther the information *detailed* of the signal. The signal is decomposed in eight groups by disassembling the wave package on three levels, using ***Discrete Wave Package Transform (DWPT)*** *or* ***Discrete Harmonic Wave Package Transform (DHWPT)***. The ability of decomposing the signal in regions of high frequencies makes from the wave package transform an attractive tool for the impulse signal analysis from the machine tools and gear-sets.

Applying with success this technique employs the understanding of their limits. For example, the selection of a corresponding size of the window is necessary when Fourier Transform is applied for short signals, which should match with the content of frequencies of the signal, which generally it is not prior known.

When the wavelet transform is applied, the wavelet function type which is used affects directly the efficiency tracking down the hidden transitory elements from the dynamic signal. In comparison with this ***Hilbert-Huang Transform (HHT)*** is based on instantaneous frequency from the intrinsic function of the signal which is analysed. Therefore, this is not constrained by the limitations regarding to the time and frequency resolutions, at which other techniques time-frequency are subject.

In order to make clearer the difference between the possibilities of those three mentioned transforms (Fourier Transform, Wave Transform, Hilbert transform); apply the transforms to the signal below.

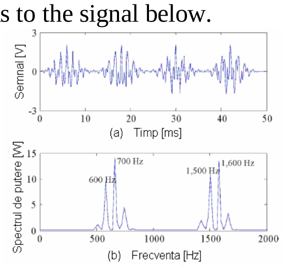


Fig. 3. Vibrations signal and frequency spectrum
(a) amplitude – time; (b) power – frequency

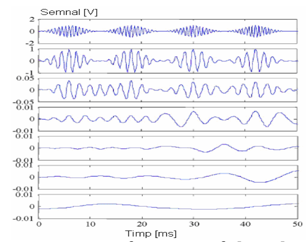


Fig. 4. Intrinsic function of the vibration signal obtained from analysis

As it is shown in the figure 3, a number of four groups of signal trays simulate the transitory signal of vibrations. Each group of impulses contains transitory elements of two central frequencies. In the first two groups, the central frequencies of the transitory elements are equal with 1500 Hz and 700 Hz, respectively two groups of impulses with central frequencies 1600 Hz and 600 Hz. The four groups are separated one from each other by a time interval of 12 ms. In the interior of each group, the two transitory elements are superposed in time. The frequency spectrum, obtained by the Fourier transform, although emphasis the four central frequencies contained in the signal, it doesn't identify any change of frequency of the transitory components.

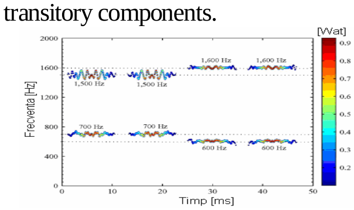


Fig. 5. Hilbert-Huang transform of the vibration signal

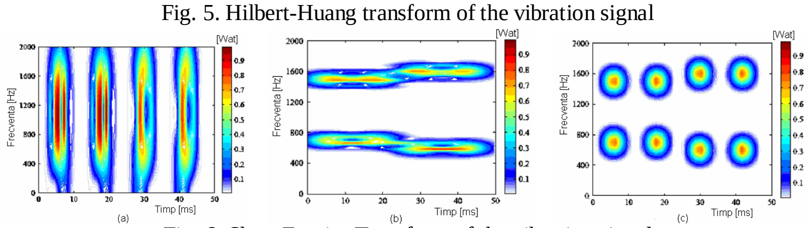


Fig. 6. Short Fourier Transform of the vibration signal
(a) window size: 1,6 ms; (b) window size: 25,6 ms; (c) window size: 6,4 ms

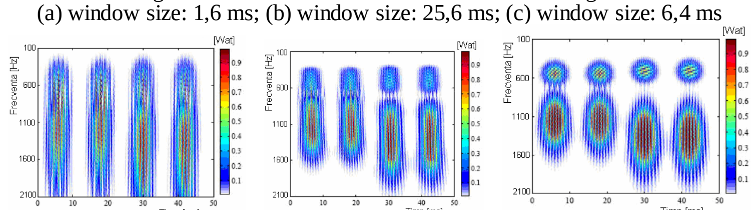


Fig. 7. Wavelet transform of the vibration signal
(a) wavelet function: Db2; (b) wavelet function: Meyer; (c) wavelet function: Morlet

In comparison with the Fourier frequencies spectrum, the analysis time-frequency of the signal on HHT base has revealed that in the interval 20-30 ms there is happening a change in the composition in frequency, from the components of 1500 Hz and 700 Hz, to the components of 1600 Hz and 600 Hz. This king of result proves the HHT efficiency in the components analysis of transitory vibrations. From the figures 6 and 7 can be observed that the identification and the differentiation of the transitory components can be done only in particular cases when it is selected a window size of 6,4 ms, in the short Fourier transform, or Morlet wavelet, in the case of wavelet transform. These results reveal the constrictions associated to the Fourier techniques time-frequency and TO (oscillation transform) and from the comparison it indicates the fact that HHT grants a viable approach of the transitory signal analysis.

Data length effect

Power spectral density of the measured signal indicates the existence of four components of major frequencies:

- f_u=10 Hz, unbalanced bearing box frequency , which appears when the gravitational centre of the bearing box doesn't coincide with its rotation centre, how it is showed in the figure 8(a);
- f_m=20 Hz, misalignment frequency, which appears when the two channels of the bearing box (interior and exterior) are not in the same plane, resulting an axis of the channels which isn't parallel with the axis of the rotation axle, as it is illustrated in figure 8 (b);
- f_{BPFO}=41 Hz, crossing frequency of the roller (ball) in the exterior channel, which is related to the periodical crossing of the rollers (balls) over a fix reference point;
- last frequency harmonica, with the value $2xf_{BPFO.}$

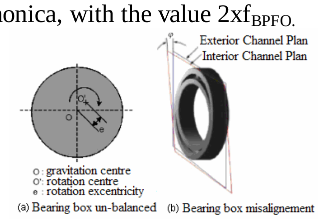


Fig. 8. Unbalance and misalignment models of the roller bearing

The relation between the value *ApEn* and the data length taken into calculus is illustrated in figure 9, where six vibration signals measured on the same bearing box are displayed comparative, under a sampling frequency of 6, 10, 14, 18, 22 and 26 KHz. It can be observed that when the data length is higher than 1000 data points, the values variation *ApEn*, with reference to each sampling frequency, approaches a small and constant value.

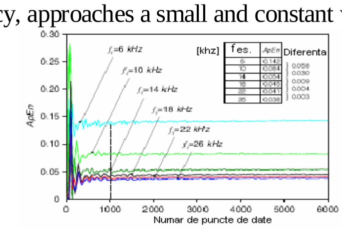


Fig. 9. Data length effect on the **ApEn** values

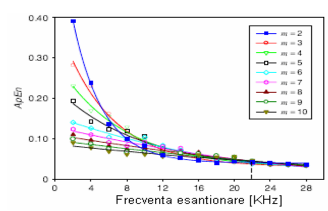


Fig. 10. Sampling frequency effect on the **ApEn** values

Tolerance effect

Another parameter that affects the calculus of the ApEn values is the tolerance *r*. As it was defined in the equation (5), the selection of *r* depends on the *k* value for a certain fix number of data points. The effect of *k* on the ApEn value calculus is showed in the figure 11, where a number of nine different dimensions *m* where evaluated to verify the consistency of the results of ApEn calculus.

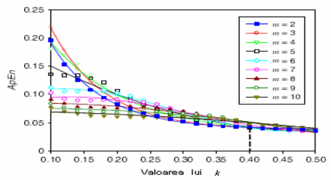


Fig. 11. Effect of **k** on the **ApEn** values

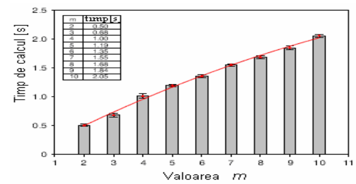


Fig. 12. Dimension **m** versus calculus time

As the value of *k* increases, the variability in ApEn decreases continuous for the adequate dimension *m*, at different rates. The difference in ApEn associated with different values *m* becomes insignificantly low, because *k* approaches 0,4. For example, at k=0,4, the variation of ApEn because of the various values *m*, is lower than 4 %. That kind of variation was considered acceptable in the present stadium, therefore the tolerance value *r* corresponding to k=0,4, was still chosen for the calculus of ApEn.

Dimension effect

As it is indicated in the equation (1), the increase of the dimension *m* will conduce to more temporal information about the signal which must be included in the ApEn calculus. Whilst the global calculus precision improves, a greater value of *m* conduces to a higher calculus cost. The evaluation was performed for k>0,4, showing that the values of ApEn hadn't considerable change beyond this value, as it is showed in the figure 13. Once the values corresponding values ApEn had changed less than 6,6 % when *m* increased from 2 to 10, it is preferable a lower value for *m* for the calculus of ApEn. Thereby in the present study it was chosen m=2.

Test signal formulation

In view of characterize quantitative the health state of a machine and it's degradation (in proportion as it increases the rigour of the structural defects), it's needed a test signal to provide a reference base. Bellow it was formulated this kind of test signal having as base some vibration signals measured at a roller bearing, as it is illustrated in figure 13. By inverse Fourier transform, four major components of frequencies identified in the signal spectrum (la 10, 20, 41 and 82 Hz) were combined with an additional noise *e(t)* to build a test signal *S(t)*. Together, the four components represent over 91% from the content of energy of the original signal. Test signal is formulated as: S(t) = X(t) + e(t)   (1)

In the equation (9), *X(t)* represents the signal rebuilt from the four components of frequencies of the original signal, and it is defined as:

$$X(t) = 0.016\sin(2\pi 10t) + 0.112\sin(2\pi 20t) + 0.325\sin(2\pi 41t) + 0.029\sin(2\pi 82t). \qquad (10)$$

The noise component *e(t)* is defined by the ratio signal - noise (SNR) as bellow:

$$SNR = 10\log_{10}\frac{\|X(t)\|_2 / M}{e(t)_2 / L} \quad (3), \text{ where: } \|X(t)\|_2 = \sum X(t)^2,\ \|e(t)\|_2 = \sum e(t)^2,$$

M and *L* are the length of *X(t)* and respective *e(t)*.

The build test signal was showed next to the measured vibration signal in figure 13.

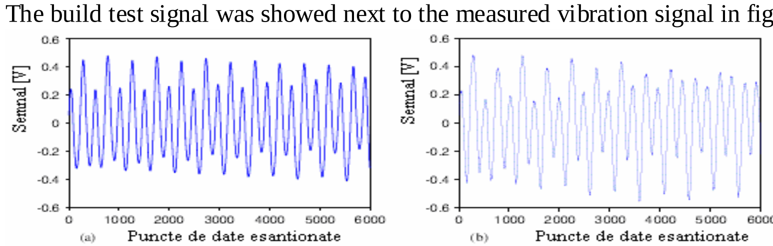


Fig. 13. Test signal formulated as a reference for quantitative evaluation of **ApEn**

Using the test signal there were calculated the ApEn values corresponding to different SNR, as it is listed in the table below.

SNR	Forma unda	Spectru	ApEn
Semnal de baza			0.073
100 dB			0.074
50 dB			0.075
20 dB			0.154
15 dB			0.259
10 dB			0.430
5 dB			0.577
0 dB			0.653
Zgomot alb			1.400

Should be noted that the value ApEn on the test signal increased over eight times, when SNR decreased from 100 to 0 dB. The decrease of SNR is reflected in the wave form by the increase of noise. This is analogue with the deterioration of the machine when the defects appear and spread in the structure. Furthermore, the addition of the noise signal to the test signal with a bandwidth increased, because the rate SNR decreased, corresponds to an ascending number of components of frequency in the signal, as it indicates the column “spectrum” from the table above. This result confirms that the value ApEn supplies a quantitative measure for the characterization of the signal degradation, which can be represented by the deterioration of the health condition of the machine.

Acoustic diagnosis

Acoustic emission (EA) is defined as transitory elastic waves generated from a quick release of energy caused by a deformation or deterioration inside or on the surface of a material. In the applications regarding the rotative machines monitoring, the acoustic emission is defined as transitory elastic waves generated by the interaction of two mediums in relative movement. The sources of acoustic emissions that can be described as processes that emit elastic waves can be classified in four groups: dislocation movement, phase transformation, friction mechanisms, creation and extending of the cracks.

The emitted signals can be divided rough in two types: continuous emission (similar to white noise) and burst type emission, the most often detected as simple sine curves decreasing because of the resonances from the structures.

The sources of acoustic emissions, in rotative machines, include impact, cyclic wariness, friction and turbulence, loss of material, cavities, and leakages. For example, the interaction of the surface roughness and the crossing of the bearing rollers over a defect in the exterior channel will generate acoustic emission. Should be noted that the surface defects, as well as the cracks and the scratches attenuate the waves and beside that the finishing of the metals surface can also influence the attenuation.

Vibrational diagnosis

All the machines vibrate. In the process of energy focusing for the needed purpose, there are generated forces that excite directly the components of the machines or by the mean of a structure. Some components from the carrier channel are accessible from the exterior therefore can be easy measured the vibrations resulted from the excitation forces.

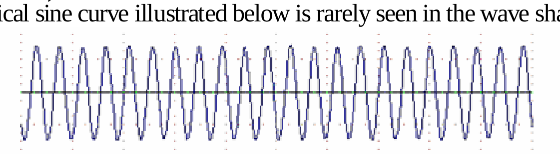
As long as the process is constant or varies only between some limits, the measured vibration will be practically constant. When it starts to appear and develop the defects in the machine, some dynamic process from the machine change and some of the force that action on the components, or the mechanical properties of the components its selves, change, influencing the vibration spectrum. This is the base for the utilization of the measurement and vibration analysis in health state monitoring. The frequency spectrum needed to be recorded is 10-10000 Hz or even higher, this including the frequencies associated with the unbalance, misalignment, rollers crossing, and the resonances of the bearing box elements. For the health state diagnosis of the machines it is performed a frequency spectrum analysis of the recorded signal (usually the vibration acceleration), and if this is not enough it is being proceed to an analysis in the time domain.

The signal analysis in the time domain

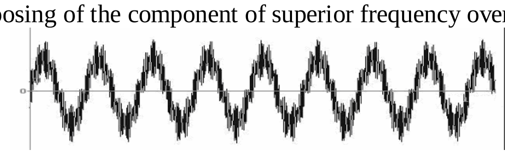
Generally, the signals in the time domain are best used by applying the model recognition principles (the pattern) and if it's necessary by calculating the frequencies components of the main events in the wave shape models. The wave shape in the time domain can be used to increase the spectral information in the following applications: applications of low frequencies (lower than 100 RPM), the indication of the amplitude in the situations when the impact appears, and also the evaluation of the defect rigour from the roller bearing, gears, weakening, frictions, and beats. In some of the cases the frequency spectrum data and the phase data gave better indications without being needed additional data supplied by the time analysis. Here are fitted in the applications: the unbalance of the rotative machines; misalignment of the rotative machines.

Signal patterns (models) in time domain.

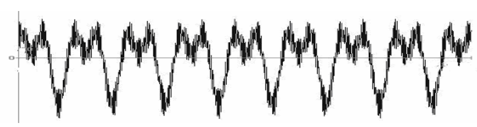
Unbalance: The classical sine curve illustrated below is rarely seen in the wave shapes of acceleration.



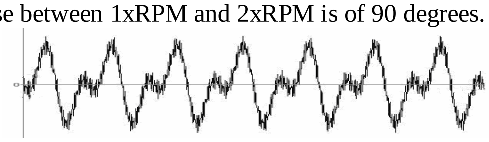
The wave shape below is more representative for the sinusoidal vibration. It is worthy to observe the superposing of the component of superior frequency over the lower frequency.



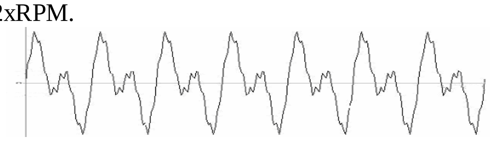
Misalignment: Although the classical symptoms of the misalignment are the forms M and W of the signal in the time domain, we can not relay on these symptoms. The relative angle of phase between the components 1xRPM and 2xRPM determines the shape or the model (pattern) of the graph.



The signal model from below illustrates the classical model of misalignment. In this model the relative phase between 1xRPM and 2xRPM is of 90 degrees.

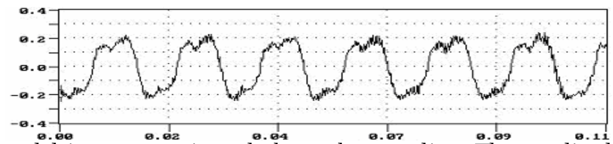


The next signal model is valid for a relative difference of phase of zero degree between 1xRPM and 2xRPM.

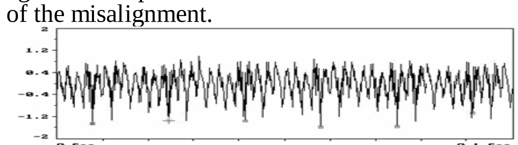


Amplitude symmetry

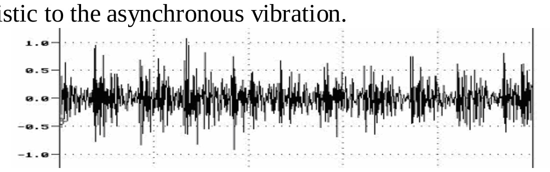
It is important to observe the symmetry of the signal towards abscise. The symmetry of the signal indicates a movement of the machine on each part of the central position, and the asymmetry of the data indicates the fact that the movement is possible constrained by the misalignment or friction. The next signal is symmetric above and under the zero line.



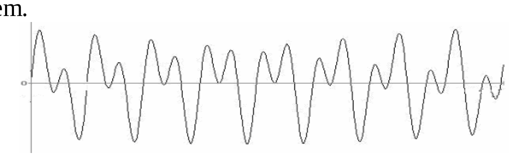
The next model is asymmetric and above the zero line. The amplitudes under the zero line are significantly higher in comparison with the ones above the zero. In this case the source constitutes the reason of the misalignment.



Time axis symmetry: In the model of anterior signal, although complex, it can be observed that the signal is still repeated with the frequency 1xRPM. This indicates the fact that the vibration is synchronous with RPM. The signal model below indicates a model that isn't repeated, characteristic to the asynchronous vibration.

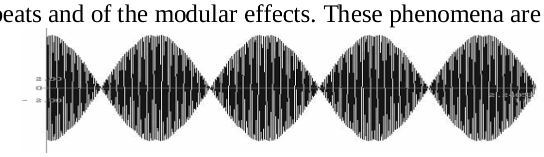


The next example is from two sources of frequencies which are not harmonically related (58 Hz and 120 Hz). This is the type of signal that can be created when a motor with two poles has an electric problem.



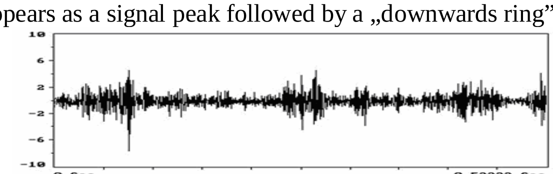
Beats and modular effect

Another excellent application for the signals in the time domain is to observe the frequencies of the beats and of the modular effects. These phenomena are often audible.



Impacts

When the FFT process is applied to a signal that contains impacts, the vibration's amplitude is often decreased. The next wave form in the time domain derives from a rotative machine with 1800 RPM. There can be observed some aleatory impacts with amplitude over 6g peak. Cause of this signal was a defect in the rollers of the bearing box. The shape of the wave form often appears as a signal peak followed by a „downwards ring".



Signal analysis in the frequency domain

Vibration signature of a machine is the characteristic model of the vibration which generates it during functioning. The signal obtained from a transducer can be considered as a signature, but the vibration's signal *spectrum* is generally considered is considered to be the *signature.* From all these non-destructive tests that can be applied to a machine, the vibration's signature is the one that contains the most important information.

Vibroacoustic diagnosis

Vibroacoustic diagnosis is practiced when the two methods of diagnosis, presented before, taken separately can not supply a complete diagnosis. Practically the vibroacoustic diagnosis consists in the combination of the two diagnosis methods for the health of the machines and namely the acoustic diagnosis and vibrational diagnosis. The selection of one of the three methods is being made function of the level of monitoring and diagnosis needed, function of the number and the rigorous of the test conditions and function of the involved costs.

DIAGNOSIS SYSTEM

The diagnosis system for the health of the machines can be simple or complex, their complexity depending on the level of the imposed performances and the application complexity. In general a system of diagnosis is composed from two big components: hardware and software.

The hardware part of the diagnosis system is composed from transducers (acceleration, velocity, and movement), conditioning modules for the signal (amplification and filtration), acquisition boards and computer. The software part is dealing with the data acquisition in the computer, the interpretation of the signals obtained after the processing and generation of the diagnosis, eventually the indication of the measures of maintenance (predictive). The software can be realised in different languages of superior level or programming mediums, one of the newest being LabView.

MAINTENANCE

Maintenance represents the totality of operations where through the equipments or equipments are maintained so that they function at optimal parameters. The maintenance operations ordinary effectuated reduce the losses caused by the malfunctions and work accidents. Maintenance can be:

1. *Corrective maintenance* – when the equipments function until their accidental stopping because of the settled wear or because of the apparition of some malfunctions. The repair means the changing of the damaged subassembly or even to whole equipment.

2. *Planed maintenance* – when the equipments are stopped when is planned, function of the number of accumulated hours in order to perform the technical inspection, current and capital reparations.

3. *Preventive and predictive maintenance* – the equipments function in safety conditions until a certain level of wear installs, or until the apparition of a defect. In this system, the equipments will be stopped at a data anticipated weeks before, and the reparation will be performed only where is needed. This system permits premature tracking, malfunction or localization and identification of the worn piece.

4. *Pro-active maintenance* – using specific apparatus, the health state of all the dynamic equipments can be tracked continuous or periodical.

In view of the state equipment evaluation, the predictive maintenance uses non-destructive test technologies as infrared, acoustic, vibration analysis, sound level measure, oil analysis and other online specific tests (in real time). The vibrations analysis is the most productive to the rotative equipments of high speed and can be the most expensive part of a program for predictive maintenance. Acoustic analysis can be performed at sonic or ultrasonic level.

CONCLUSIONS

The Acoustical Emissions Technique is a developing multi-discipline and it is now the centre of intense researches and studies based on applications. The richness of the discovered knowledge, generated and disseminated in this discipline that takes amplitude is itself the proof of the various applications. The interest in the development of new technologies to pass over all the problems that weren't solved until our days, from the domain of monitoring and of the diagnosis applications of the complex industrial machines, grants opportunities for the Acoustical Emissions Technique to develop without impediments. This is reflected in a significant increase of the global request of sensors for Acoustical Emissions. With an accelerated speed for increasing intelligent information, the sensor and the data acquisition technologies, combined with quick progress in the domain of intelligent processing of the signal, it has been anticipated a healthy increase of using Acoustical Emissions in many sectors of the engineering, fabrication, processing and medicine. The application of Acoustical Emissions in prediction hasn't been fully realised and developed.

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