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DIAGNOSTIC PROCESSES IN MECHANICAL ENGINEERING PRACTICE

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Abstract: *The suitable technical diagnostics with following measures resulting from real state is one from the decisive implements for increase of plants service ability. The technical diagnostics is defined as the process at that the topical technical state of objects is detected on the basic of objective evaluating symptoms determined with measuring technique means. Exerting diagnostics is possible with regard on a phase of machine or device life.*

Keywords: Diagnostic processes, vibrodiagnostics, harmonic signals, energy

1 INTRODUCTION

In practice the double- level diagnostics occurs. On a lower level the diagnostics prohibits to immediate origin of a relevant failure by diagnostics of the machine nodal point that presents the failure e.g. the failure of bearing and the estimate of time till the termination of the service life. Repair maintenance operations are as a rule aimed at the exchange of the damaged nodal point. On a higher level the diagnostics is more integrated and is aimed at disclosing primary causes that stimulated the premature failure of the given nodal point. In this case it is researched why it comes to the wear of the bearing nodal point e.g. the cracked machine frame can cause it and therefore the larger loadings are in the monitored bearing also at normal working conditions. If the bearing is un-lubricated or over-lubricated the careless maintenance can cause it. And it can be caused also by the damaged cover of the bearing through that the undesirable impurities get into working space. The higher level of diagnostics is more pretentious but it is possible by it to increase substantially total reliability of the machinery respectively the machine.

Diagnostics in essence rests in measurement of single changes and the following evaluation of the given nodal point technical state. The mutual additional energetic connections work between single kinematics nodal points and therefore it is not sufficient often to judge the resultant technical state on the ground of one nodal point measurement only. In dependence from the measured and evaluated quantity we distinguish various sorts of diagnostics:

- Thermo-diagnostics.
- Acoustic diagnostics.
- Vibro-diagnostics.
- Flaw-detection diagnostics.
- Tribotechnical diagnostics.
- Further methods of diagnostics.

2 VIBRODIAGNOSTICS

Arbitrary mechanical motion is always connected with vibrating demonstration of machineries and machines. Vibrations are spread in the parts of the machine in all directions likewise as light or sound. Oscillating towards some quiet position shows the surface of the bodies. Amplitudes of oscillation have periodical or accidental character. We can measure them by sensing of deflection, speed or acceleration. Among these three quantities the exact mathematical coupling is. Therefore theoretically only one record is sufficient and it is possible to count the other two quantities. Mathematical description of harmonic signal is following:

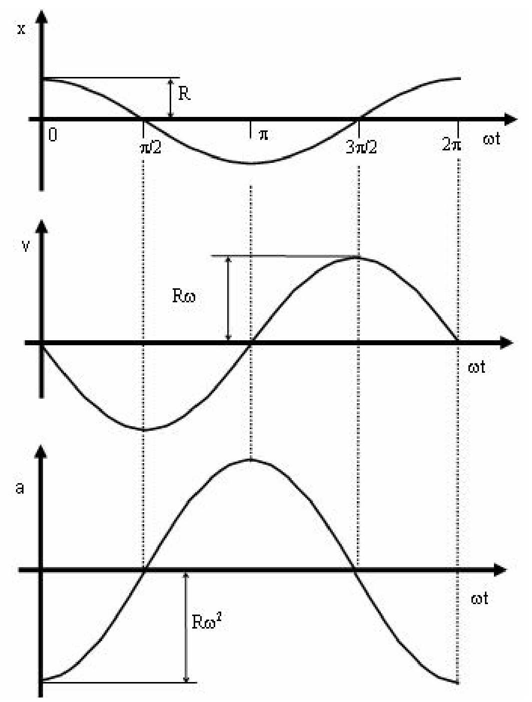

Fig. 1 Mathematical description of harmonic signal

$$x = R\cos(\omega t + \varphi) = R\sin(\varphi t + \varphi + \pi/2)$$
$$v = \dot{x} = -\omega R\sin(\omega t + \varphi) = \omega R\cos(\omega t + \varphi + \pi/2)$$
$$a = \ddot{x} = -\omega^2 R\cos(\omega t + \varphi) = \omega^2 R\cos(\omega t + \varphi \pm \pi)$$

We call a signal a time record of vibration by arbitrary quantity. If the shape of the signal after certain time is repeated the given signal is called the periodical signal. In the opposite case it goes about the casual signal. In both cases however we know to define some time section of the record that we shall consider for the longest period T.

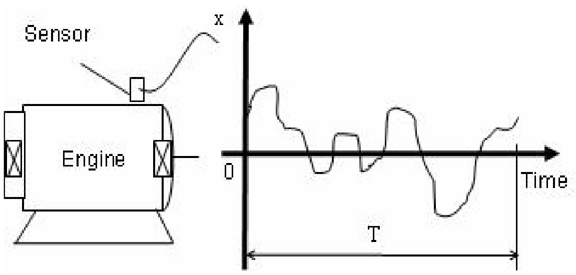

Fig. 2 Time record of vibration by arbitrary quantity

The given record also arbitrarily complicated we manage theoretically to decompose on the sum of simple sinusoidal courses of vibration that we call the harmonic signals. The decomposition is performed by Fourier's transformation or filtration methods.

This possibility of decomposition is the advantageous for analysis of the signal and its intuitive interpretation. At derivation of general properties of complicated signal we go out from it that it what is valid for the harmonic signal it will be valid also for the sum of harmonic signals.

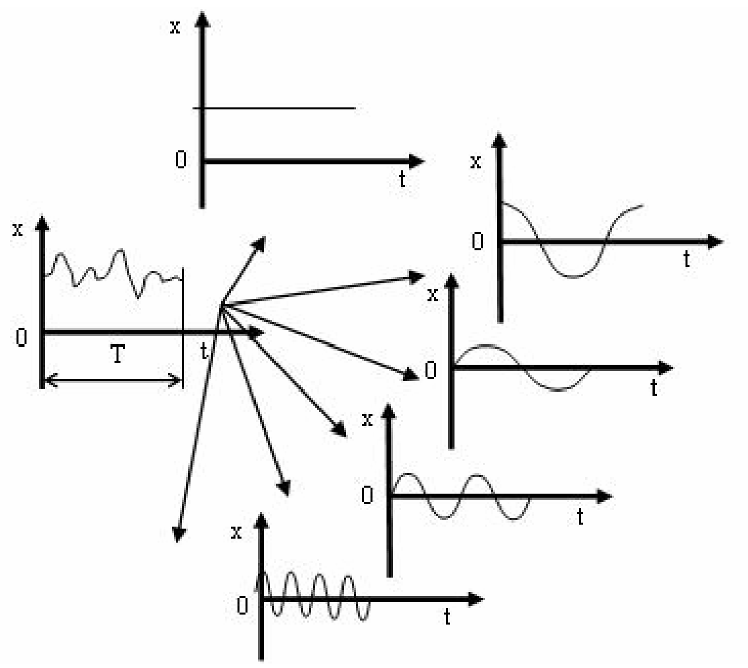

Fig. 3 Sinusoidal courses of harmonic signals vibration

3 SINUSOIDAL COURSES OF HARMONIC SIGNAL VIBRATION

The harmonic signal forms the basis of all signals. It is derived from two basic models in nature. It is the equable motion in circle and vibrating motion of material point suspended on spring. In electro technical practice as oscillating motion of current and voltage in generators or RLC (resonance circuit) circuits. The fundamental mark of signal is that is spread from the place to the place during certain time. This transmission can be realized by waving in the given medium.

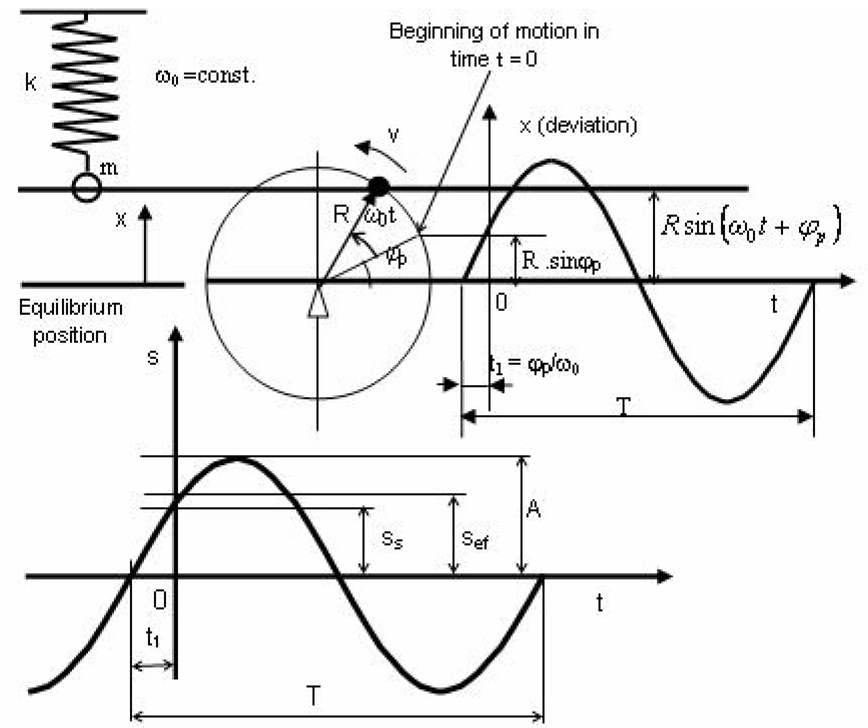

Fig. 4 Sinusoidal courses of harmonic signal vibration

s(t) – signal in dependence on time [s]
φ_1 – phase angle of signal in time t [rad]
ω – angular frequency of signal [rad/s]
f – frequency of signal [1/s] [Hz]
T – maximal period of signal [s]
A – amplitude of signal [unit is given by the type of the measured signal]

Corresponding relations:

$$\varphi_1 = \omega . t_1$$

$$s(t) = A\sin(\omega t + \varphi_1)$$

$$\omega = 2\pi f \qquad \omega = \frac{\varphi}{t}$$

$$T = \frac{1}{f}$$

On the graph in our case it is:

Absolute mean value of the signal:
The further important characteristic of the signal is its mean value s_s expressed as follows:

$$s_s = \frac{1}{T}\int_0^T \sqrt{s(t)^2}\,dt$$

Absolute mean value of the harmonic signal is:

$$s_s = \frac{1}{T}\int_0^T |A\sin\omega t|dt = \frac{1}{2\pi}\int_0^{2\pi} |A\sin\varphi|d\varphi = \frac{4A}{2\pi}\int_0^{\pi/2}\sin\omega t dt = \frac{2A}{\pi}[\cos\omega t]_0^{\pi/2} = \frac{2A}{\pi}$$

Effective value of the signal:

$$s_{ef} = \sqrt{\frac{1}{T}\int_0^T s(t)^2 dt}$$

Effective value of the harmonic signal is:

$$s_{ef} = \sqrt{\frac{1}{T}\int_0^T (A\sin\omega t)^2 dt} = \sqrt{\frac{A^2}{2\pi}\int_0^{2\pi} (\frac{1}{2} - \frac{1}{2}\cos 2\varphi) d\varphi} = \sqrt{\frac{A^2}{2\pi}\left(\left[\frac{\varphi}{2}\right]_0^{2\pi} - \left[\frac{\sin 2\varphi}{4}\right]_0^{2\pi}\right)} = \frac{A}{\sqrt{2}}$$

Top value of the signal:
It is the maximum positive or negative value of the centred signal of the given time record of the signal. We take the largest period T i.e. the period of signal for the record length.

$$s_v = \max(s(t))$$

Top value of the harmonic signal is the amplitude of the signal A.

Mean (middle) value of the signal:
At the centred signals when mean value of the signal is on zero line mean value of the signal equals to zero. It is valid also for harmonic signal. Mean value is calculated according to the following relation:

$$s_p = \frac{1}{T}\int_0^T s(t)dt$$

4 ENERGY AND OUTPUT OF SIGNAL

The substantial difference is between work and energy despite of it that both quantities are expressed in equal physical units. Work is the transmission of some quantity of energy from the object on other one with help of the force interaction:

A= F. S

F – Force
S – Course on that the given force works on the direction of motion

Energy is ability of mass to do work. At the same time total quantity of energy of closed system remains constant. (Closed system is such one that in direction to its environment emits no kind of energy).

Such a closed system is also an oscillating body suspended on non-material spring if we do not consider a damping. Otherwise told it is a harmonic oscillator. The harmonic oscillator does not work with direction to its environment. It performs however an internal work in framework a potential energy transformation kinetic one on the contrary. Output is a work performed in time unit.

$$P = \frac{A}{t} = F.v$$

If we follow the transformation of the kinetic energy only then we can talk about the output of oscillating. The greatness of the immediate kinetic energy of the system in the time unit is the immediate output of oscillating. It does not go about the measure of the energy transformation therefore we do not derive energy according to time. On the basis of it the time course of the output is with form corresponding with the course of the kinetic energy. The relation gives the kinetic energy:

$$E_K = \frac{1}{2}mv^2$$

The immediate output of oscillation:

$$P = \frac{m}{2}\frac{v^2}{t}$$

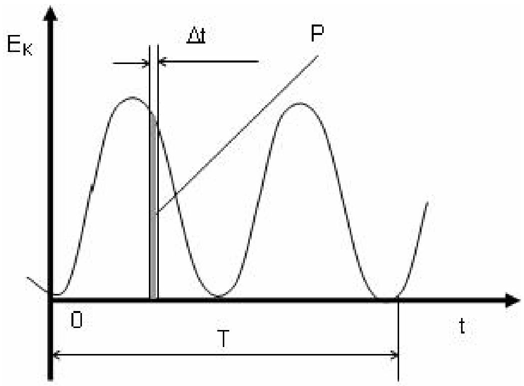

Fig. 5 Average output of oscillation in small time unit

Average output of oscillation in small time unit is:

$$P = \frac{m}{2}\frac{v^2}{\Delta t}$$

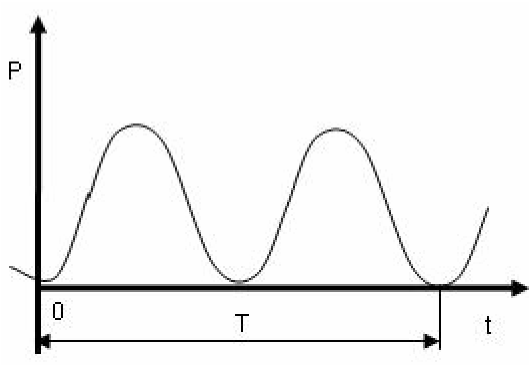

Fig. 6 The immediate output of oscillation

The output of vibrating body depends also from physical quantities but simultaneously is given by the shape of the signal. With regards on it that we evaluate various physical quantities that have a periodic course it is suitable to consider with geometrical quantities only and so to introduce a notion output and signal energy that is independent from physical quantities (temperature, speed, deflection, acceleration…). The signal substitutes an arbitrary quantity in this case. The output of the harmonic signal will be without physical dimension:

$$P_S = (\cos \omega t)^2$$

Since an arbitrary signal is the sum of the harmonic signals a general formula is valid for the signal output:

$$P_S = s(t)^2$$

S(t) - time course of the signal.

The mean output of the signal in one period will be:

$$P_{ST} = \frac{1}{T}\int_0^T s(t)^2 dt = s_{ef}^2$$

Simultaneously it is a square of signal effective value. From the physical standpoint of we consider real quantities then kinetic energy connects directly with the output of oscillation respectively the square of oscillation speed is proportionate of the output of oscillation. The energy of the signal for whole time course then will be:

$$E_S = P_s T$$

$$E_S = \int_{-\infty}^{\infty} s(t)^2 dt$$

T- Time of signal following has the infinite value in our case.

4 CONCLUSION

The diagnostics is at the same time an inseparable part of machines maintenance. In the maintenance function there is a small area only that does not exploit the diagnostics of machinery state directly. They are the prescribed maintenance works that are exerted irrespective of actual state of machinery e.g. the interchange of automobile motor oil after running certain number of kilometres or the interchange of hydraulic power unit in the airplane after flying certain number of flied hours. All these methods of the maintenance go out from the certain theoretical and statistical data of machine parts wearing out. Of course also at this type of maintenance the state diagnostics can be exerted and on the results basis to decide about the maintenance interference. The reason why it is not exerted rests in absence of available diagnostics technique that would be hereby reliable and advantageous with price for working this object.

Distinguishing critical state when the maintenance interference is just suitable prolongs the time of single parts utilization, e.g. it is not necessary to interchange oil if it has still suitable mechanical and chemical properties on the other hand it can be exacting on time and costs to find out reliably an actual oil state also with prediction of time and service life. The solution is a simple interchange with reliance on statistical course of the failure state development.

Simultaneously due to development of diagnostics methods and electrical engineering the diagnostics is introduced also into the area of planned periodical maintenance with firm intervals marked as HTL (Hard Time Limit) maintenance. The diagnostics becomes a more advantageous economically. Of course the type of maintenance is with it changed on interval type.

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