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A

Absolute shaft vibration sensor

An eddy-current displacement sensor and a vibration velocity, or a vibration acceleration sensor, are both built into one casing. This sensor combination is radially installed at the shaft and thus measures the relative shaft vibration, the absolute casing vibration and the relative position of the shaft within the shaft clearance (eccentricity). Measurement of the absolute shaft vibration is carried out through the phase-corrected addition of the absolute casing vibration converted to vibration displacement (single, resp. double integration) and the relative shaft vibration. When a vibration velocity sensor is employed for casing vibration measurement, as a rule a sensor response linearization circuit is also required.

Absolute expansion

See Casing expansion

Absolute motion

Vibration, absolute

Absolute sensor; seismic sensor

A. are sensors which acquire the motion of the measured object relative to a reference system which is at rest or one which has monotonous motion (inertial system). They are also designated seismic sensors because the inertial properties of a mass (seismic mass) are used for the measurement. The motion of the seismic mass relative to the coupled surface determines the output signal.
Typical A. are vibration acceleration and vibration velocity sensors.

Note: Vibration acceleration sensors operate in a frequency range below the resonance frequency of the seismic system, and vibration velocity sensors and displacement sensors operate above.

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AC

Alternating current

AC recording

A recording of pure AC signals (alternating quantities) by means of a magnetic tape instrument.

AC measurement

The general designation for measurement of alternating quantities. In terms of vibration technology this means measurement of a time-based vibration signal.

AC Signal

An alternating signal (alternating quantity), i.e. a signal $x(t)$ which alternates in magnitude and polarity and which over a longer time period has a mean value (equilibrium component) of zero.

Examples are technical alternating voltages and the vibration signals from vibration velocity and vibration acceleration sensors.

AC/DC Signal

A mixed signal (mixed quantity), i.e. a signal $x(t)$ which alternates in magnitude and polarity which over a longer time period has a mean value (equilibrium component) that is not equal to zero. Examples are the vibration signals from non-contacting shaft vibration sensors.

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Acceleration

Vibration acceleration

Accelerometer

Vibration acceleration sensor

With accelerometers the conversion of a mechanical vibration motion into an electrical signal is achieved by using the piezo-electric effect of a quartz crystal. In contrast to a vibration velocity sensor the spring-mass system is high-tuned, i.e. the sensor operates below its resonant frequency.

With accelerometers that operate according to the compression principle, piezo-electric ceramic discs are preloaded together with a mass. When vibrations are introduced the mass exercises an alternating force on the discs whereby, as a result of the piezo-electric effect, a charge is produced. This charge is proportional to the acceleration force and is converted by a (normally) built-in charge amplifier into a proportional voltage. Due to the construction of accelerometers very high resonance frequencies are reached. For industrial applications this is normally in the region of 35 kHz. With this construction the piezo-ceramic forms the spring in the spring-mass system and makes possible a limiting frequency of approx. 20 kHz and a lower operating frequency of approx. 1 Hz.

A linearization circuit is not required with accelerometers. The vibration acceleration proportional output signal can, when required, be converted through single-integration into a vibration velocity signal and through double-integration into a vibration displacement signal.

Attachment of the A. to the measurement point can be made similarly to vibration velocity sensors, i.e. with a probe rod, a magnetic adapter or by means of a threaded stud.

Access permission

Access permission designates persons or programs as having particular access rights. As a rule, access permission is controlled with passwords.

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Access time

For an authority, the time interval between that point in time at which a task to transfer or accept specific files is assigned, assuming valid permission, and the point in time when this transfer or acceptance is complete.

Accuracy class

An indication for the characterization of the quality of measuring instruments. The A. arises from the display error, related to the measuring range final value, in individual cases also to the scale length. This is determined by the margin of error.

An instrument with a display error of $0{,}05\ \%$ belongs in the A. $0{,}05$. In practice normally used A. are e.g. $0{,}05;\ 0{,}1;\ 0{,}2;\ 0{,}5;\ 1{,}0;\ 1{,}5;\ 1{,}5;\ 5{,}0$.

Accuracy

A statement about the quality of a measurement device.

Acoustic emission

Influence from sound (on an area or one point of the radiated area).

Acoustic emission

Designation for sound radiation.

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Acoustic velocity

Designation for the speed change assigned to sound.

Acoustics

The technology or field of science which embraces occurrences in the creation, spread, processing, detection and assessment of sound.

Active one-port

An equivalent circuit consisting of a resistor (internal resistance) and a voltage source (open circuit voltage source) in series with the internal resistance or a current source (short circuit current source) parallel to the internal resistance.

Active transducer

Transducers for which the energy of the output signal comes, at least in part, from other sources than the input signal.

Adjustment

Adjusting a measuring device in order to eliminate the systematic measurement deviation as far as it is necessary for the intended application.

Air-borne sound

Sound transmitted through the medium of air.

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Alarm delay

The A. is a function, or a functional unit, in conventional machine monitoring systems. Through this function an alarm is produced upon a limit value violation only when the limit value is continuously exceeded for the entire predefined time delay. The limit value is violated during the delay time period. If during the time delay the measurement falls back within the limit value, no alarm is produced and the A. is automatically reset. With a new alarm limit violation, the procedure starts again. Suppression of the alarm is dependent upon the time period of the increase in the measurement and not on the amount of the increase in the measurement.

ALARM limit

The A. can be at very different levels for various machines. Commonly the selected values are determined with reference to a base value which is revealed by experience of the measurement directions at the respective machine.

See also Limit values for operation

Alarm relay time delay

See Alarm delay

Alias effect

A phenomenon that occurs when a dynamic signal is sampled at a sampling rate that is lower than double the frequency of the highest frequency component in the signal. High frequencies can appear lower in the frequency spectrum. If the input signal is passed through a low-pass filter (anti-alias filter) before being sampled the effect can be prevented. The cut-off frequency of the low-pass filter must be smaller than the half sampling frequency. The disadvantage of this technique – as it is with all filters – is that the phase of the vibration component is falsified dependent upon the frequency.

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Aliasing

Alias effect

Alignment

A. is understood to be the activity through which two or more machines are positioned so that their rotational axes coincide, or are flush, at the couplings under operational conditions. The goal of A. is, according to VDI 2726, to couple the individual machines in such a way that when setting up with the connected drive and machines, clutches and shafts, as trouble-free a running condition as possible is attained.

Alignment error

When shafts are connected together without a coupling error whereby the bearings are not correctly positioned then an A. exists. This is normally governed by the mounting and three types of errors can be distinguished:

- Parallel displacement
- Angular displacement
- Parallel and angular displacement

With an A. the coupling flanges cannot be connected together without force and without deformation of the shafts. As a consequence the shaft rotates around a fixed (non-circulating) deformed axis of rotation, which leads to rotating and bending loading of the rotor (the rotor is “milled“).
The typical constraining forces of an A. lead as a rule to an additional very high static loading (but also relieving) of the bearing in a constant direction (“spatially-fixed bearing reaction forces“), which can result in a reduction of the bearing life. It should be noted that the ideal rotor which has purely an alignment error excites no vibrations because no alternating forces occur.

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Alignment report

Description of the factually achieved end condition after alignment (actual values).

Alignment shims

Metal plates of different thickness, which are inserted between the machine feet and the base (foundation) to achieve exact vertical adjustment of the machine or for the elimination of a tilting or soft foot condition.

Alternating oscillation; in acoustics: complex sound

Alternating event

Alternating pulse; bipolar pulse; double pulse

Pulse, bipolar

Alternating quantity

An alternating quantity means every physical quantity (such as potential, current, mechanical oscillations, etc.) whose instantaneous value is a periodic function of time with an average of zero.

Alternating voltage

An alternating voltage is a fluctuating electrical potential whose instantaneous value is a periodic function of time with an average value of zero. In the simplest case, this function is sinusoidal: the potential performs harmonic oscillations.

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AM

Abbr. for **A**mplitude **m**odulation

Amount indicator

1) In a balancing machine the display for the amount of unbalance or its effect.
2) With a vibration measurement or a vibration monitoring instrument, the display for the magnitude of the measured or monitored vibration characteristic quantity.

Amount of unbalance

The measurement of unbalance in a rotor (related to one level) without taking into account the angular position of the unbalance. It is measured as the product of the mass of the unbalance times the deviation of its centre of gravity from the shaft axis. Units for the amount of unbalance are, for example, gm-m or oz-in.

Amplifier

An active two-port network, designed in its essentials to produce an output signal having more power than that of the input signal.

Note: An amplifier can also be used as a filter or to accomplish alternative signal processing. A transmission link for which the output has a (usually larger) value that is exactly dependent on the value of the input. Depending on the type of quantity to be amplified, distinction is made between voltage amplifiers and current amplifiers. Depending on the value of the signal level, distinction is made between preamplifier and power amplifier, and depending on the necessary degree of amplification, distinction is made between one-stage and multi-stage amplifiers. By amplifier stage, we mean the smallest closed circuit that can function as an amplifier. With a multistage amplifier, the individual amplifier stages are multiplied for the total amplification effect.

Amplitude

The maximum instantaneous value $\hat{x}$, the peak value of a sine quantity x means its amplitude.

Note: The word A. should only be used with peak values of sinus-shaped or at least vibrations which are sinus-related.

Given that

$$x = Re\left\{\hat{x}e^{j(\varphi_0+\omega t)}\right\} = Re\{\hat{x}e^{j\varphi_0}e^{j\omega t}\} = \left\{\underline{\hat{x}}e^{j\varphi_0}\right\}$$

the complex quantity is

$$\underline{\hat{x}}e^{j\varphi_0}$$

which characterises the sinus quantity concerning amplitude and zero-phase, its complex A. or indicator (s. DIN 5483) [6] and DIN 5475 sheet 1.

Note 1: To distinguish the complex A. it is recommended that one of the characterised complex quantities be used, e.g. the underlining (s. DIN 5483).

Note 2: The concept “vector“ or “vibration vector“ which is often used for the description of the complex A. should be avoided and replaced by the concept “indicator”.

Amplitude and Phase versus Time

A graphic diagram that illustrates the amplitude and phase of a harmonic vibration as a function of time (e.g. in a trend diagram).

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Amplitude-amplitude characteristic

Amplitude of the basic vibration of the output signal of a dual-gate as a function of the amplitude of a sinus-shaped input signal at a predefined frequency.

Note: The frequency of the basic vibration of the output signal can differ from the frequency of the input signal.

Amplitude-frequency characteristic

Amplitude of the basic vibration of the output signal of a dual-gate as a function of the frequency of a sinus-shaped input signal at predefined amplitude.

Note: The frequency of the basic vibration of the output signal can differ from the frequency of the input signal.

Amplitude demodulation

Demodulation, employed on a modulated signal which has been created by amplitude modulation. Separation of the low-frequency information signal from a high-frequency carrier by means of a peak value rectifier circuit.

The converse is Amplitude modulation.

Amplitude modulation

Abbr.: AM
Modulation, with which the amplitude process of a periodic carrier - generally linear – is the instantaneous value of the modulating signal.

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A. is a method by which the amplitude of a constant carrier vibration is superimposed with the fluctuations of a lower frequency vibration, i.e. the amplitude of the carrier vibration is changed with the rhythm of the frequency of the lower frequency vibration (modulated).

In communication technology the information to be transmitted is displayed in the form of amplitude variations in the carrier vibration. These amplitude changes work in the diagram like a symmetrical "Envelope", which shows up both in the positive as well as in the negative vibration area. The A. should not be confused with an overlay. The A. has the disadvantage that under circumstances of a superimposition - e.g. due to disturbance radiations on the cable – the usable information signal can no longer be recovered by demodulation.

Amplitude modulator

Modulator

Amplitude scale, linear

The quantity is displayed as an absolute value. The amplitude axis is thereby scaled in a linear fashion between the smallest value (as a rule zero) and the largest value.

See also Amplitude scale, logarithmic

Amplitude scale, logarithmic

The representation of a quantity as a relationship, which is formed from an absolute value and a reference value, on a logarithmically scaled axis. With scaling in dB (decibel) the reference value is always assigned to the scale value 0 dB.

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A

A substantial advantage of the logarithmic amplitude scale during the representation of spectra exists in the fact that percentile changes of components independent of the absolute amounts always lead to the same length variations of the represented spectral lines.
See also Amplitude scale, linear

Amplitude spectrum

Distribution of the amplitudes of the partial oscillations of a signal or noise as a function of the frequency.

See also Amplitude spectrum of periodic vibration

Amplitude spectrum of periodic vibration, complex

Each summary of amplitude and phase spectrum is called a complex amplitude spectrum.

Amplitude spectrum of periodic vibration

The application of the $\hat{x}_n$ amplitudes of the partial oscillations (a periodic vibration) over its frequency or over its ordinal number is called A.

Note: The A. is not sufficient in order to determine the time course of the periodic oscillation. For this the additional indication of the zero-phase angle is necessary. These depend however, like the allocation of the partial oscillations in sine and cosine parts, on the respective choice of the start time. The A. is independent of this and knowledge of it is sufficient for many purposes.

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Analogue

1) Similar procedures have temporally dependently a continuous curve of values.

2) Representation of a signal or a number in a non-quantized form, i.e. not as a number, but e.g. in the form of an electrical quantity (voltage, frequency). The analogue representation method stands in contrast to the digital representation method.

Analogue circuit

Electronic circuit constructed in analogue technology.

See also circuit technology

Analogue-Digital-Converter

<analogue – to digital converter>

Abbr.: ADC

A functional unit which converts an analogue input signal into a digital output signal (s. DIN 19226). A portion of accuracy is lost if the value lies in analogue form between the discrete value possibilities of the digital form.

See also Analogue-Digital-Conversion

Analysis in Frequency and Time domain

Wavelet Transformation

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Analysis in Time domain

Time domain

Analysis with constant absolute bandwidth

A. laid over a linear frequency scale results in the same resolution along the frequency scale. Thereby it is easier to identify harmonics and sidebands in the spectra. In addition a better resolution results in the case of high frequencies, than would be the case with analysis using a constant relative bandwidth. A disadvantage exists in the reduced frequency range, which covers only approx. 1.5 decades.

Analysis with constant relative bandwidth

A. and the representation of the results of the analysis can be made, in contrast to the analysis with constant absolute bandwidth, by a wider frequency range (normally over 3 or 4 decades). It corresponds also to an analysis with a constant Q-factor (quality factor). A disadvantage exists in the increasingly poor resolution in the case of higher frequencies.

Angle-equidistant

In equal angular intervals.

Angle indicator

1) A device to display the angle of unbalance.
2) For vibration measurement devices, the display of the phase angle of the rotational frequency signal components and higher harmonics. The phase angle in this case is referenced on the angle reference mark fixed to rotor.

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Angle modulation

Modulation, for which the phase angle of a sinusoidal carrier is a special function of the momentary value of the modulating signal.

Angle of unbalance

A polar coordinate system in a plane perpendicular to the shaft axis that rotates with the rotor is given. The unbalance angle is then the angle at which the unbalance mass lies in this coordinate system.

Angle reference generator

A setup during balancing that produces a signal through which the phase angle setting of the rotor is defined.

Angle reference mark

A mark on the rotor that identifies an angular reference system fixed to the rotor. It can be of an optical, magnetic or mechanical nature.

Angled tilting foot; angled soft foot

Tilt-base

Angular frequency; angular frequency of a sine vibration
<angular frequency>

The $2\pi - multiple$ of the periodic frequency is known as the angular frequency (formula character ω).

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Remark: The usual name A. is the primary name; since this expression tempts however the misunderstanding that the frequency of the rotation of a complete circle is meant, the name A. is recommended. A. stands briefly for unit angular velocity.

Angular offset

Misalignment

Anisotropic support

<anisotropic support>

Uneven bearing stiffness (support) of a rotor in the radial planes, i.e. unequal rigidity and damping characteristics in the radial directions of the bearings. The converse is the anisotropic bearing support.

Anisochronous

Marks a time-dependent feature, a time slot pattern or a signal, whose and/or its successive significant times are separated by time intervals, which all have the same forced calculation period or periods which are an integral multiple of one basic period.

Anisochronous signals

Signals, anisochronous

Anisochronism

Condition, in which a time-dependent feature of a time slot pattern or a signal is anisochronous.

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Anisotropy

Direction dependence of physical properties. The converse is isotropy.

Example: Different stiffness and damping factor of foundations and bearing supports in the horizontal and the vertical directions. Different rotor stiffness in generators due to pole slots.

ANSI

Abbr. for <**A**merican **N**ational **S**tandard **I**nstitute>

National Standards Committee of the USA. This corresponds to the DIN in Germany.

Anti-Alias-Filter

A band-limiting filter used in sampling systems to prevent falsification by undesirable superimposition on the spectral function.
A low-pass filter employed in digital spectrum analysers to prevent the alias effect. The theoretical usable signal frequency range is reduced depending upon the steepness of the filter flanks.

Anti-resonance

Feature which in a system in forced oscillation every change of the exciter frequency, even a small one, causes an increase of the exciter response of the system.

Note: The quantity, which serves as a measure for the excitation response, must be given, e.g. vibration velocity anti-resonance.

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Aperiodic

The characteristic of a strongly damped signal quantity, without which when the signal fades away due to the *damping*, vibrations arise.

Arc second; angular second

Designates an angle unit of 1/3600 degree, common with alignment. An angular displacement (alignment error) of exactly one arc second corresponds to a coupling gap of $1/1000\ mm$ at an operating diameter of $2{,}062\ mm$.

Arithmetic processor

A special processor, which is supplied to a universal processor and which is particularly for the fast execution of certain arithmetic operations (e.g. floating-point addition, subtraction, multiplication, division or vector operations and matrix operations) and is hardwired as coprocessor in a computer system. Thus the A. for which it is particularly laid out, implements these operations very much faster than a freely-programmable universal processor and thereby relieves and/or increases the processing speed of the overall system.

Assessment of shaft vibrations

The execution of shaft vibration measurement is often made difficult due to inaccessibility. Depending upon range of the measuring task one measures in or two radial directions (appropriately shifted by $90°$) and then evaluates the following measurements:

- The maximum excursion S_{max}, i.e. the largest value of the kinetic shaft orbit, or
- The largest vibration amplitude S_{p-p} from both sensors.

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The measurement of axial shaft vibrations is less common. This is done only in special cases, e.g. at the free pinion end of double-diagonally toothed spur gears for monitoring the normal operational wear of the teeth [25].

Assessment of bearing vibrations

In the first place this is the assessment of the rms value of vibration velocity (also called vibration speed) as well as the vibration displacement. Vibration acceleration is preferably consulted for monitoring rolling-element bearings and gears. Vibration velocity is measured either directly with vibration velocity sensors (seismic sensors) or with piezo-electric acceleration sensors and an inclusive single integration of the measured signal. With both sensors the vibration displacement can be evaluated through a further integration step. According to the extent of the measurement task, measurement in one or two (effectively 90° displaced – as a rule horizontally and vertically) is done or, as the case may be, also in the axial direction.

Assessment of machine condition, diagnostic

Diagnostic evaluation of machine condition

Assessment of machine condition, global

Global evaluation of machine condition

Asynchronous

Events which are not coupled with one another in a fixed manner are asynchronous. The converse is *synchronous*.

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Asynchronous vibrations

Vibrations, asynchronous

AT Bus

16 Bit Data-bus in AT-computers.

Attachment

Attachment type for vibration sensor, vibration sensor attachment

Attachment through a three-point support

This is the case when the vibration sensor is attached or held against the object being measured, without taking any special measures, whereby there are basically only three points of contact. This type of attachment is only to be used when low frequency (200 Hz and lower) vibrations will be measured. At higher frequencies contact resonance can occur resulting in large measurement errors. The vibration sensor may only be attached to the measurement object in a simple manner when the acceleration magnitude to be measured is considerably lower than the level at which the sensor will detach, so that lifting off of the sensor or wandering on the measurement surface will be prevented.

Attachment using a probe

When a probe is used there is also a very small area of contact between the measurement object and the vibration sensor. With this attachment type measurement at any point on the machine is realized in a practical manner. However in spite of this advantage the use of a probe requires a great deal of caution.

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This attachment contains the danger of contact resonance in the operating frequency range. Measurement of high-frequency vibrations should not be carried out using a sensor with a probe.

Attachment of vibration sensors though an intermediate fluid layer

This exists when the vibration sensor is coupled to the measurement object over a layer of oil or thin grease so that is it easily moved in the tangential direction. Thus the sensor ‘swims’ on the fluid layer and for this reason only forces and motion perpendicular to the measurement point are transmitted to the sensor. This attachment type is practical only for sensors which have a centre of gravity near to the attachment surface. Furthermore its employment is limited because such a loose coupling to the measurement surface is not always usable, e.g. in the case of a perpendicular surface.

This attachment type is very stiff in the perpendicular direction, but on the other hand tangential motion and displacement of the measurement object are practically not transferred to the vibration sensor at all. Thus this attachment type is suitable only for measurement of vibration components in the direction of normal attachment at the measurement object. For this reason it is also not usable for torque vibration measurement. This fluid layer attachment also allows an error-free coupling for very high frequencies up to 10 kHz. This contributes toward an increase in directional selectivity of the measurement arrangement and prevents false measurements with measuring devices that are sensitive to displacement. It is especially important to note that a fluid layer coupling can only be used with measurement surfaces that are flat and smooth where there is no possibility of catching on a protrusion between the measurement object and the sensor.

Attachment of vibration sensors through an extensive, fixed mechanical connection

This exists when the largest part of the vibration sensor is so in contact with the measurement object, that forces and motions perpendicular and also parallel to the contact surface are transferred to the vibration sensor. This kind of coupling can be realized by gluing, soldering to, attaching with adhesive wax and by firmly pressing or screwing on with a plastic intermediate layer such as lead foil or the like. With very firm pressure this coupling already occurs also without an intermediate layer by plastic deformation of the surfaces being pressed together.

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Attaching the sensor, instead of merely applying it, is in most cases recommended. Often it is not only important to fasten the sensor perfectly relative to vibration but beyond that it must be guaranteed, to prevent damage to the item under test or to the vibration sensor, that it does not separate and drop off. This kind of attachment permits such a good connection to the item under test that also high frequencies from 1 to 10 kHz in a high order of magnitude can be correctly measured. If any intermediate media such as adhesive wax, lead foil, etc. are as thin as 0.1 mm, then with sufficiently light sensors having a large surface area the contact resonances will be above the kHz range. Attachment with adhesive wax is particularly favourable, since because of the high internal damping of the material the resonance increase will be very weakly emphasized.

With A. movements of the item in a tangential direction under test will also transfer to the measuring instrument. Therefore it can also be used for measuring vibration events which occur parallel to the surface and for torsional vibration measurements.

If vibrations perpendicular and parallel to the surface are present, then measuring errors can occur with this kind of attachment if the directional sensitivity of the measurement sensor is not sufficiently selective. This is in particular completely valid if the vibration component which is to be measured is only of the same magnitude or smaller than a perpendicular component. In this case a vibration sensor with very narrow directional sensitivity must be selected.

With A. expansions of the item under test will also be transferred to the sensor. They cause tension in the measuring device parallel to the coupling surface. These expansions occur in vibrating bodies due to mass forces and shear stresses. They can cause large measuring errors, if the vibration sensor is sensitive to expansion. This is possible e.g. with piezoelectric acceleration adapters with thickness vibrators. In this case expansions of the item under test can produce tensions in the vibration sensor which simulate a measurement result, even if no measured variable is present in the normal or tangential direction. The occurrence of such expansion features is to be avoided particularly with sheet metal which produces bending vibrations. One should seek to avoid faulty measurements produced by expansion features by employing measuring devices which are less sensitive to this characteristic, e.g. acceleration sensors with bend element.

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Attachment types for vibration sensors

The different kinds of attachment types can be divided regarding their physical impact preferentially into the following groups:

- Attachment through an extensive, fixed, mechanical connection
- Attachment through an extensive connection by means of an intermediate fluid layer
- Attachment through a three-point surface contact
- Attachment by means of a probe

Attitude angle; steady state

Angle between the direction of the radial load working in the rest position through the bearing centre (e.g. by gravitational pull of the earth) and a line from the bearing centre through the shaft centre.

Audio

Description of the range of human hearing from approx. $20 \ldots 20{,}000$ Hz.

Audio frequency

Frequency in the audible range (between 16 and 20,000 Hz approximately).

Auto-correlation function

A function which indicates the similarity of a time function $x(t)$ and the retarded function $x(t-\tau)dt$ and which can be calculated according to the formula

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$$F_{xx}(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T x(t) * x(t-\tau)dt$$

Availability

The probability that a unit will be found in functional condition.

Average access time

Time in milliseconds as to how long it takes on average from the time an access command is given until the desired data are found on a medium. The value depends mainly on the mechanics of the drive, i.e. how fast the read/write head is brought into the respective position. Peak values for hard drives lie below 10 milliseconds. Average values are between 15 and 20 milliseconds.

Averaging of frequency spectra
<averaging of frequency spectra>

Instabilities of the machine such as number of revolutions and variations in load, impacts and shocks, or also stray effects of vibrations from neighbouring machines, lead to the fact that with a frequency analysis the individual spectrum cannot provide representative results. This spectrum is rather a “random recording“. To get an authoritative frequency spectrum the following averaging procedures are common:

- RMS averaging (root-mean-square averaging)
- Exponential averaging
- Time interval averaging (synchronous averaging)
- Peak value determination (peak-hold)

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Averaging of spectra, quadratic; **RMS averaging**

Quadratic A. is particularly used if the values of the individual vibration components vary strongly. As a result of the quadratic A. of several successive measurements one receives a better conception of the average values of the individual vibration components.

During the averaging procedure the preselected number of spectra is acquired and averaged. The same weight is given to each single spectrum, thus same influence on the averaging value. After conclusion of the averaging process, the average value is retained until a new averaging process is started. A further result is available only at the end of the most recent averaging process.

During the averaging process the quadratic average value of all oscillation components becomes A below; in the spectrum the A. is from the sum of the squares of the individual amplitude values of the individual measurements j:

$$A_i = \sqrt{\frac{1}{k}\sum_{j=1}^{k} A_{ij}^2}$$

The quadratic A. has in summary the following characteristics:

- Averaging is done in the frequency domain.
- The result is a pure linear weighted averaging of the amplitude squares of the individual frequency lines over time.
- The phase is not taken into consideration.
- The result is more representative the more spectra are averaged. The statistical measurement error is reduced according to the relationship:

$$\Delta A_1 = \frac{\Delta A_{ij}}{\sqrt{k}}$$

- Through the averaging process noise components are not reduced but are more accurately measured.

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The quadratic A. improves the statistical accuracy of a noisy spectrum, but is **not** able to reduce the noise level. Apart from the information about the vibration components in the spectrum one receives averaged information about the statistical strength of the noise in the entire frequency range.

Averaging, synchronous, Time-domain averaging

For the averaging procedure a consequence is acquired in such a way by j time signal blocks that they always have the same position within the time window at one trigger point (synchronous collection).

By linear averaging of the sampled values $a(t_{ij})$ congruent in the time signal blocks at the respective time t_i, according to

$$a(t_1) = \frac{1}{k}\sum_{j=1}^{k} a(t_{ij})$$

all signal portions, which have a temporally firm reference to the trigger signal, are retained, while all other signal portions are especially effectively weakened.

Synchronous A. is an effective procedure, in order to reduce the noise levels in spectra. Thereby small signal components frequently only become recognizable at all in spectra.

Synchronous triggering which can be used for synchronous A. (thereby also the designation synchronous A.) can be derived from the time signal, if a suitable periodic slope is present in the signal. Usually however external triggering with a phase reference sensor is used.

The signal components, which have a firm reference to the number of revolutions of the machine, are retained; all other signal portions are averaged out. This procedure works like a filter for rotational-frequency signals and their harmonics.

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Average value

<average value>

There are various possibilities for defining the A. of a finite number of real numbers of $X_1 \dots X_n$. The most commonly used are:

a) The arithmetic average value:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

b) The median (central value): Its definition is simplest to clarify, if one regulates the n numbers of $X_1 \dots X_n$ according to size. The middle number in this series is the median. If n is an even number, one selects the number in the $n/2$-th position.

c) The modal value: This is that number, which occurs most frequently in the n numbers of $X_1 \dots X_n$. The modal value does not have to be clearly defined.

d) The geometric average value (is only defined for positive values $X_1 \dots X_n$):

$$\bar{x} = n\sqrt{X_1 X_2 \dots X_n}$$

Average value, quadratic, of a vibration

<quadratic averaged value of vibration>

See Effective value

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A

Averaged value of vibrations

Apart from the deflection of a vibration, A. considers also the course over time. In practice one rarely uses A. for the quantitative description of vibrations.

The index description is average, e.g. acceleration $a_{average}$. Also the term “arithmetic average value“ is commonly used.

The A., e.g. of vibrations, is defined as follows:

$$S_{average} = \frac{1}{T} * \int_0^T |s| \, dt$$

In special cases the harmonic vibration is valid.

Average values; arithmetics

See Average value

Average value, geometric

See Average value

Average shaft position

See Shaft position, average

Encyclopedia

A

Axial

Operation or measurement in the direction of the shaft axis. The adherence to a uniform measuring direction is recommendable, e.g. from driving machine to driven machine.

Axial ball bearing

A ball bearing that bears the axial thrust in one direction. A larger contact angle, characterised by high opposite shoulders (thus also the description shoulder bearing) of the inner and outer races is required for this application. When two bearings of this type, arranged back-to-back, are installed, bi-directional forces can also be absorbed.

Axial position

Axial rotor position (or its variation) in relation to a fixed reference point. Normally the thrust bearing position, or a component of the casing near to the thrust bearing, is the fixed reference point. The measurement is carried out by axially arranged displacement sensors.

Axis of rotation

The A. is the straight line about which a body rotates. With rigid bearings the rotational axis coincides with the shaft axis; with non-rigid bearings this is not necessarily the case. When the bearings are not isotropic (anisotropic) there is no stationary rotational axis.