

# **How to start with vibration diagnostics**

Method guide



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## **Introduction**

The purpose of this method guide is to briefly describe actions, which are needed to establish vibration diagnostics. Emphasis is on description of fundamental steps so that the reader is able to start with practical diagnostics in the shortest possible time. That means diagnostic measurements, evaluation of data and, above all, output protocols for maintenance management.

In this guide it is presumed that the reader has no prior experience with vibration diagnostics.

The practical procedures are described but it is not explained in depth why these procedures are carried out in the specified way. More detailed knowledge can be obtained by specialised training, literature study, etc. Manuals for specific named components and programs are not a part of this guide.

## **Tasks of vibration diagnostics**

When we talk about vibration diagnostics, we mean the regular measurements, whose main task is to:

1. Detect a change in operational state of a machine
2. Determine cause of the change
3. Recommend a maintenance action (repair, adjustment, lubrication, etc.)
4. Check the result of the maintenance action (including inspection of disassembled parts for confirmation of analysis).

Basic vibration diagnostics has two main goals:

1. Diagnostics of mechanical state of a machine (unbalance, misalignment, looseness, etc.) - **MS**
2. Diagnostics of roller bearings - **RB**

Other special tasks exist, which can be partially solved using the basic procedures. These tasks require special methods and instruments (sensors) for a successful diagnosis. One example is diagnostics of friction bearings.

## **Basic rules**

- 1. Increase of measured vibration values with time indicates a change of operational state**
- 2. Constant measured vibration values indicate a stabilized operational state**

It does not necessarily indicate a good state. For instance, in the case of poor assembly of bearings, measured values of vibration will be high right from the start. These values will stay constant for some time (bearings will withstand the load), then the values will start to grow quickly and the bearings will be damaged. Lifetime of such bearings may be hours, days, weeks or, sometimes, even months.

- 3. Reliability of diagnostics will never reach 100%**

Breakdowns, which develop in a shorter span of time than the time of regular measurements, may always happen. The breakdowns caused by material fatigue may develop in a few seconds (cracks, breaks). The effectiveness of diagnostics is demonstrated mainly by reduced maintenance costs (not to zero), and a reduction of unexpected shutdowns (not complete elimination).

**4. A consistent usage of norms applies only to special machines for which special norms exist**

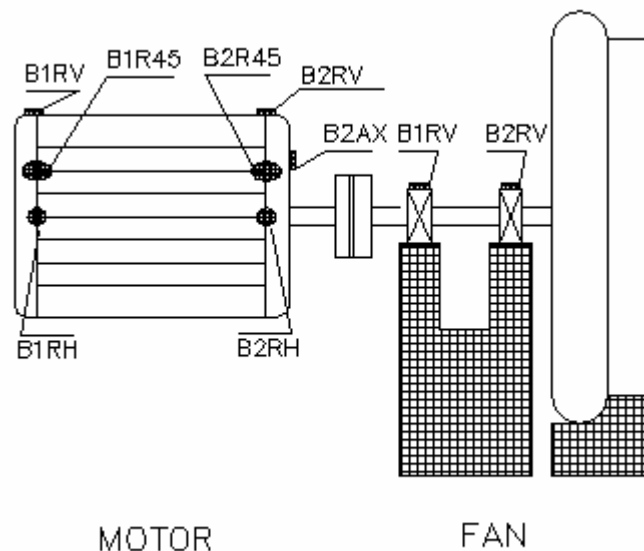
It is not possible to simply define limit values of vibrations generally for a wide range of machines. Instead, it is possible to create norms for special machines (for instance turbines). These norms are powerful tools for a diagnostician. General norms only recommend how to define limit values. Specific values stated in norms can only be used when no other possibility exists to obtain values valid for a specific machine.

## Measurement points

To judge development of operational state of a machine, the conditions for individual regular measurements must be like as much as possible for each measurement.

### **Choice of measurement points**

The sources of vibrations in rotational machines are the forces that are caused mainly by unbalance. In piston machines it is also unbalance of the rotating parts and forces that originate from the piston movement. The vibrations used for diagnostics of roller bearings (RB) are an exception (in part). Vibrations are caused by the forces originating from the roll-off of the balls (cylinders), mainly due to unequal trajectories, wrong tolerances, wrong choice of bearing type, overloading, under-lubrication, etc. Diagnostics of the state of roller bearings is a basic requirement of the user in an overwhelming majority of cases. Information about the state of bearings is contained in higher frequencies of measured signal. Higher frequencies have an unpleasant property of being quickly absorbed - depending on the distance from a bearing. Measurement points are therefore chosen so that the transmission of the vibrations is damped as little as possible. That means they must be closest to the part, which is the source of vibrations. If this is not possible, a machine part in the firmest contact with the incriminated part should be chosen. No hoods or covers should be chosen. The part must always have the highest possible stiffness – due to the influence of stiffness on transmission of high frequencies. The measurement points chosen with regard for diagnostics of bearings will be usually suitable also for diagnostics of mechanical state (MS). That means unbalance, misalignment, mechanical looseness, etc. These are the states, which are diagnosed on lower frequencies (approx. up to 1000 Hz). Such frequencies are not significantly damped and can be measured on many machine parts. If it is not possible, it is necessary to create still more points. It is always necessary to obtain measurements in the radial and axial directions. Machine behaviour can be very different in the vertical and horizontal directions.



The picture shows a typical choice of measurement points. It is necessary to choose the closest point for each of the four bearings (RB measurement). The radial directions are usually chosen. The axial direction is then only added for the measurement of MS. Measurement points for diagnostics of both RB and mechanical state (MS) are used for measurements in the radial directions.

### **Marking of measurement points:**

No fixed rules exist for marking of measurement points. We recommend to use always the same designation as in the maintenance. Direction of marking of measurement points is usually chosen from the machine drive towards the driven part. The same applies in the case when a machine set should not be divided into separate machines. One should concentrate on the position of the bearings and mark the points accordingly. It is up to the user to understand the machine as two parts (for instance motor and ventilator, i.e. bearings B1, B2 for motor and B1, B2 for ventilator – see the picture) or as one machine (i.e. bearings B1, B2, B3, B4). The picture shows one usable system of marking.

<b>L x xx xx</b>	<b>L</b>	= bearing
<b>x 1 xx xx</b>	<b>1</b>	= sequence number of bearing in the machine
<b>x x Rx xx</b>	<b>R</b>	= measurement direction relative to the axis of rotation – radial
<b>x x AX xx</b>	<b>AX</b>	= measurement direction relative to the axis of rotation – axial
<b>x x xV xx</b>	<b>V</b>	= measurement direction relative to the gravitation – vertical
<b>x x xH xx</b>	<b>H</b>	= measurement direction relative to the gravitation – horizontal
<b>x x xx 45</b>	<b>45</b>	= measurement direction relative to the gravitation in degrees (direction is neither H nor V, e.i. horizontal = 0, vertical = 90)

### **Methodology of route measurements**

In order to be able to follow the state of all machines, the vibrations must be regularly measured in the chosen measurement points. The measured data is stored and evaluated in a computer. The process of measurement and transfer of data to the computer is called route measurement. Route means the list of machines, which are supposed to be measured together. It would be ineffective to measure the machines separately and go away after each measurement to transfer data to the computer. Route is therefore a prescription (map, trail) of movement on the company's premises within one measurement. Computer holds the list of all machines in your company that you want to diagnose. The list has a tree structure for easy orientation.

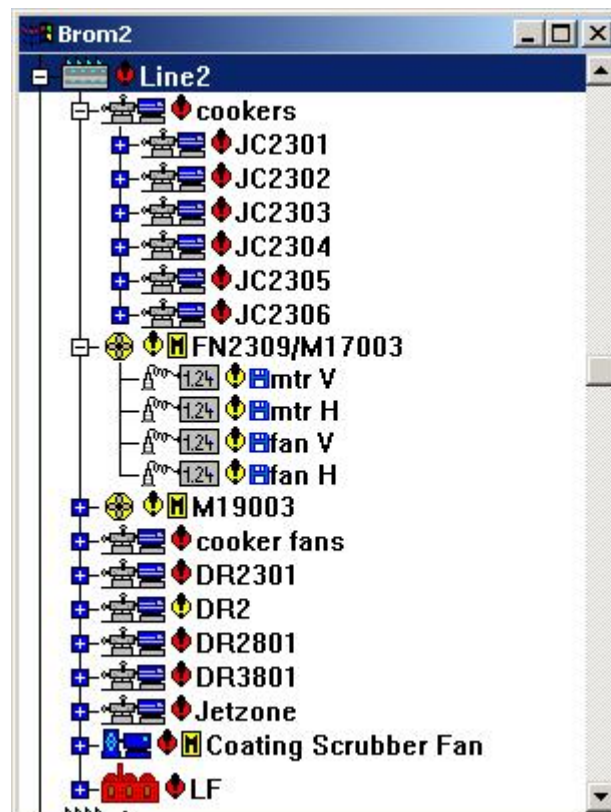
One complete measurement cycle consists of these phases:

1. Choice of machines to be measured, in the computer. The list is called a route. For the time being it is empty because the machines have no new measured data. The next task is to transfer the route into a measuring instrument.
2. The user leaves the office and goes to measure all machines. The instrument shows the list of required measurements. The user gradually visits all machines in the route and gradually makes measurements at all measurement points on each machine.
3. When all required measurements are done, the data is stored in the instrument. After returning to the office, the data is transferred to the computer. It is ready for evaluation.
4. Next, the user evaluates the data. The result is a report for the maintenance team or the company management.

### **Determination of the names of groups, machine sets and machines**

Evaluation of the measured data is done using a computer program. First, a structure of your company (that is a list of all machines) must be created in the program. Usually, a four level structure of machine designation is selected. These are the Plant, Machine Group, Machine, and Measurement Point. The actual structure depends only on the user, it does not effect quality of diagnostics. Again, we recommend to create only names and structures which are known to the workers on the plant. It is advisable to choose unambiguous designations of machines and measurement points in order to eliminate the danger of measurements at wrong points.

**If you make a measurement at a wrong point, it is later difficult to discover and it may have a fundamental influence on your evaluation!**



The picture shows an example of a division into groups, machine sets and machines as it is displayed in the computer program. Assignment and designation of measurement points to a relevant machine and group is evident. It is unadvisable to create multilevel structures with long names because of a limited width of the display on the measuring instrument. It would make orientation in the structure difficult and it would increase probability of measurement at a wrong point.

## **Preparation of a measurement point.**

### **What is a measurement point**

A simple answer is that it is a point where we make a measurement. To obtain a quality measurement, the points for measurements must be prepared in advance. For regular measurements the sensor must be always fixed in the same way at the same point. For diagnostics of bearings it is necessary to fix the sensor with a magnetic pad or, even better, with screws. Do not fix the sensor just by hand – higher frequencies cannot be measured in this way. Fixing with screws is used less for practical reasons – the preparation takes longer. Most users fix the sensor with a magnetic catcher. The catcher is firmly screwed to the sensor and then it is magnetically fixed to the metal surface of the machine. Hence the sensor is fixed and a measurement is possible. Quality of fixation markedly influences the result of your measurement. If the sensor swings or jumps about etc., your measurement is pointless. A layer of paint is also a big obstacle for higher frequencies. Surface of the magnetic catcher is ground and the same surface quality must be created on the machine. In practice, it is not possible. A flat surface 3x3 cm in size can be ground only in a workshop. Anyway, quality of the bearing's housing steel is not high and such a surface can quickly succumb to corrosion. Then it becomes unusable. Solution to this problem is to use measurement pads. These are the cylinders with the diameter approx. 26 mm and height 10 mm with a ground surface, made of a magnetic stainless steel. They are fixed to chosen points with special glue, which ensures a perfect transmission of the high frequency vibrations. The pad is covered with a plastic cover, which is removed only for the measurement. Another advantage of the cover is that when the machine is painted, your measurement point is preserved. The paint would devalue the pad.



It is sufficient to coarsely grind the machine's surface and degrease it before the pad is glued. Durability of the pads in time is unlimited. In practice, it is always until a forcible removal.

### **Types of measurement pads**

Two basic types of pads are supplied for preparation of the measurement points. The first is a simple measurement pad for well accessible points on machines. The second is a special T pad for measurement on electromotors (fixed in the radiator ribs). Both pads have an M6 thread for fixing a sensor.

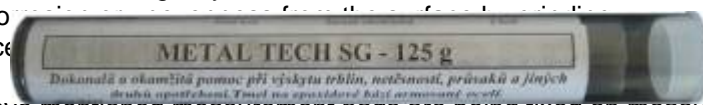


### Instalation of measurement pads

You will need mainly the following aids: angle grinder, set of files, emery paper, degreaser (ethanol, solvent), measurement pads and glue.

Prepare the surface in the following way:

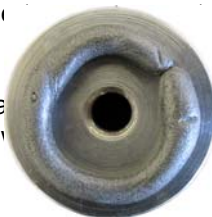
- remove the paint, coating
- degrease the surface



Both types of the above mentioned measurement pads are being fixed on measurement points with the METAL TECH SG cement. Other glues with similar properties may be used.

The METAL TECH SG cement is a 2-component epoxy cement with properties best suited for this task. The material, after mechanical mixing, chemically react and after drying they form a hard material, resistant to moisture, temperature and humidity.

In the case of the measurement pad the procedure is as follows: cut-off a disc approx.3 mm thick from the cement. Wet your fingers and work the disc into a homogenous lump. Roll a cylinder 2-3 mm from this lump and put it on the side, which is not roughened.



Push the pad with glue to the prepared place and, while constantly pushing and turning the pad there and back with circular movements, observe that the cement is being evenly pushed out along the circumference of the pad. The purpose is to make the layer between the pad and the surface as thin as possible.

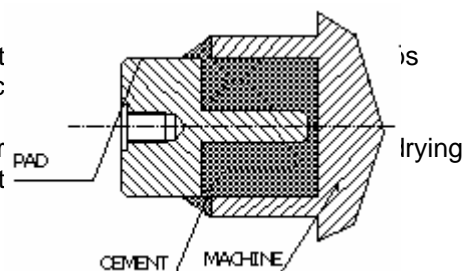
**! ATTENTION. CEMENT MUST NOT BE PUSHED OUT COMPLETELY!**

The pushed out cement may be removed or levelled out around the pad. In the end you put a cover on the pad.

When using the pad and it is necessary to clean the surface of the cement.



the cement is dependent on the amount of the cement to process. The surface must be well cleaned and degreased so that only the cylindrical part remains. In the end put a cover on the pad.





# **Measurement**

## **Measurement conditions**

For a successful measurement, evaluation and monitoring of the signal development (trend) it is important to ensure that the measurement at individual points is always made under the same operational conditions. These are mainly the machine's rotational speed and load (output). Besides, as a matter of fact, the sensor must be well fixed at the measurement point, either magnetically or with screws. When these principles are not observed, the vibration values in different operational regimes are measured but the trend of an operational state of the machine cannot be reliably followed. The values show large variations. Such differences are related to different operational conditions while measuring. A special measurement procedure must be chosen for machines that change operational conditions very quickly, for instance machines with operation under load lasting several tens of seconds like the lifts or arms with small uplift. In such a case the measurement must be done only within the load time. Therefore it must be determined in advance in what regime the machine is to be measured. Repetitive measurements must be made at equal revolutions. The rotational speed must not be changed within a measurement. This applies also to other individual routes. Contrary to the rotational speed, there is not such a great emphasis on the change of the load as long as it is not extreme (double). It would be a fundamental error to measure individual routes in different regimes, for instance at idle running and subsequently at full load. Such measurements are not usable for monitoring the trend of operational state of the machine.

The place and surface for the measurement is secured by bonding the pads to the measurement point. Another factor, which can influence the measured values, is the pushing force holding the sensor on the pad. Variations in the pushing force significantly influence the measured values. Therefore the sensors pushed with hand are unusable.

The best approach is to use a magnetic catcher. It is a pot magnet with housing made from magnetic stainless steel, which has an M6 thread for the sensor fixing.



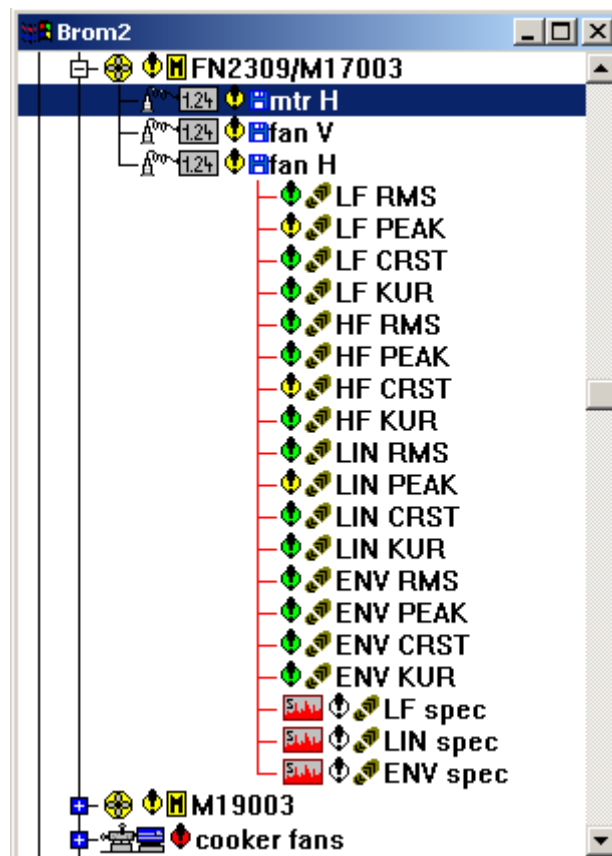
The magnetic catcher ensures constant pushing force on the measurement pad. When working with the magnet it is necessary to keep the measurement area clean and use a protecting cover. Strong magnetism can cause contamination of the contact surface. It is then very difficult to clean.

## Processing of measured data

The methods of evaluation of measured data are determined by the level of measuring instruments. The lowest level is to write down the data from an instrument display. This is suitable for small plants where small number of measurement points does not warrant acquisition of powerful software. Only the static wide-band values of the basic vibro-diagnostic measurements are monitored at such plants. The goal is to find out defects like faulty bearings, unbalance, misalignment, mechanical looseness, resonance, etc.

In large plants with a large number of machines where a large amount of data is obtained with the goal to measure all static and dynamic values, it is necessary to use software for evaluation of the measured values. The software displays graphs of the measured spectra and time records and has a possibility to print outputs in the form of statistics or operational reports.

In the DDS 2000 environment it is possible to create the above mentioned route tree using a chosen schema with a division of levels down to a measurement point. The point, as is obvious from the picture, is formed by data cells (end branch of the tree) in which the measurements are stored.



Nomenclature of the individual groups, sets, machines and measurement points is entirely up to the user but the designation of a data cell is determined by the choice of the signal path.

## **Choice of measurement types**

Now the measurement points are prepared and their list is created in the database. The types of measurements, which are going to be regularly carried out, must be chosen for each point.

### ***Detection and analysis***

First, we will explain the basic structure of the work of a diagnostician. The basic task is to monitor operational state of the machines and evaluate whether it is stabilized (without changes). If an increase of vibration values is detected then its cause must be determined and a correction action recommended to the maintenance team. In professional jargon these activities are called DETECTION (inspection) and ANALYSIS. The reason for this division is to ensure effectiveness of the diagnostics. The task of detection is to measure as frequently as possible at as many machines as possible. It is not possible to employ complicated and lengthy measurement methods for each measurement. Only simple and quick methods can be used. The number of measurement points must be minimized but it must be ensured that these measurements are sufficient for detection of the change of operational state (that is starting disturbances, wear, adjustment, lubrication, etc.). Correct setup of the diagnostic detection is always a question of correct choice of simple methods.

If a change of values (usually an increase) is found at regular detection measurements, then it is possible to determine its cause either directly (the results of the detection measurements are sufficient for analysis) or further measurement can be done using more sophisticated methods.

### ***Setting for common machine types***

It is suitable to choose wide-band measurement of the speed and acceleration for common types of rotational machines (pumps, ventilators, etc.) for detection. The measurement of the mean frequency of oscillation in the band up to 1000 Hz is a standard type of measurement. Its task is to find defects like unbalance, misalignment, mechanical looseness, etc. – that is to monitor mechanical state. The measurement of acceleration in various bands is then mainly an indication of the state of the roller bearings. In the case of the range of instruments Adash 4000 and common machines, we recommend to define the following types of measurement for detection:

LF-RMS	(mean frequency of oscillation in 10 – 1000 Hz band)
HF-RMS	(special parameter for the state of the bearing, mean acceleration in 5 – 16 kHz band)
LIN-RMS	(wide-band parameter, mean acceleration in 0,8 Hz – 16 kHz band)

The parameter HF can be replaced by the parameter HF-ENV, which is an envelope analysis in the 5–16 kHz band. We recommend it for machines working in the stabilized regime because it is more sensitive than HF and in the case of change of the machine's regime it can change its value. This could cause difficulties when evaluating data because trend of the values is influenced by two factors – the state of the bearing and the regime of operation.

## **How to set up detection measurements in the case of non-standard types of machines?**

It is necessary to distinguish two cases:

1. Atypical machines with stabilized operation, for instance transmission gears, machines with friction bearings, machines producing impacts, reciprocal (e.g. piston) machines, screw compressors, etc. The choice of suitable methods of measurement usually requires an initial analytical measurement. The result serves to recommend a detection method. Detailed explanation is beyond the scope of this publication. Here we shall briefly outline only the basic cases.

### Transmissions

Usually the standard LF-RMS, HF-RMS and LIN-RMS are measured. It is important to understand that the wear of the gearing will manifest itself in a similar way as the wear of the bearings. It is necessary to distinguish these cases in the analysis (e.g. by using the disturbance frequencies of the bearings).

### Friction bearings

Oil film dumps very much all agitations coming from the shaft. Increase of the acceleration values is usually evident only when the rotor starts to hitch. It is sufficient to measure only LF-RMS a LIN-RMS and consider using a non-contact measurement of the shaft vibrations with on-line system. Such a system is economically demanding, hence it is a question of the machine importance.

### Impact machines

The mean values of vibrations do not produce good results. It is better to measure the peak values LIN-Peak a LF-Peak. The best approach, also for detection, is to measure time signals LF, LIN.

### Reciprocal machines

A suitable combination is usually LF-RMS, LIN-RMS, LF-Peak, LIN-Peak and HF-RMS.

### Screw compressors

The standard LF-RMS, HF-RMS, LIN-RMS is not sufficient. It is necessary to measure also the spectrum LIN and carefully follow its development. The wear of the bearing is usually screened by the tooth frequency of the compressor.

## 2. Machines with irregular operation.

The following principle applies to such machines – always measure in the same type of operation. For instance when measuring on a feeder, which moves products from a belt to pallets, it is convenient to choose the moment of gripping and measure while lifting and turning. These moments can be very short. This must be considered when working with an instrument to be sure that the measurement was done at the right moment. Measurement of time signals is often applied in these cases for the purpose of detection.

If an uncertainty exists about the setting of your measurements, always investigate the situation. You can take advantage of the services of ADASH spol. s r.o. on the web page [www.adashservice.cz](http://www.adashservice.cz). You can send photos of a machine and the results of your first analytical measurements. Effective advice to reach a solution is possible, usually without a need for an external financially demanding measurement.

## **Analysis**

Description of all possibilities of analytical measurements is beyond the scope of this publication. Generally speaking, it is always measurement of time signals, spectra, series analysis, etc. In practice, it is not necessary to use them very often because detection methods alone can unambiguously determine many defects. For an understanding of analytical methods and their successful use we organize a lot of trainings and, above all, we help the users with evaluation of data from the specific

machines. We offer a system of consultancy with the goal to help you to achieve, in the shortest possible time, a visible success in diagnostics.