UNIT-4
MACHINE HEALTH MONITORING

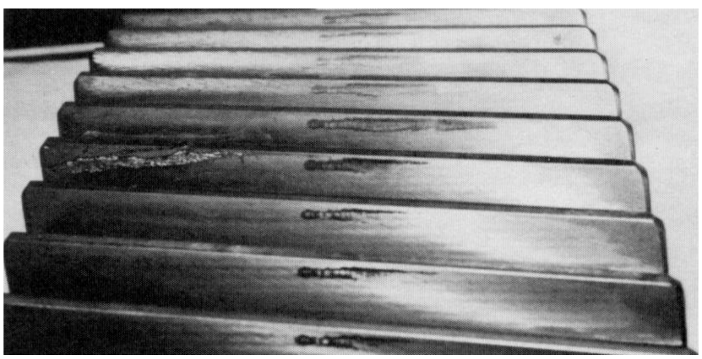
4.1 INTRODUCTION

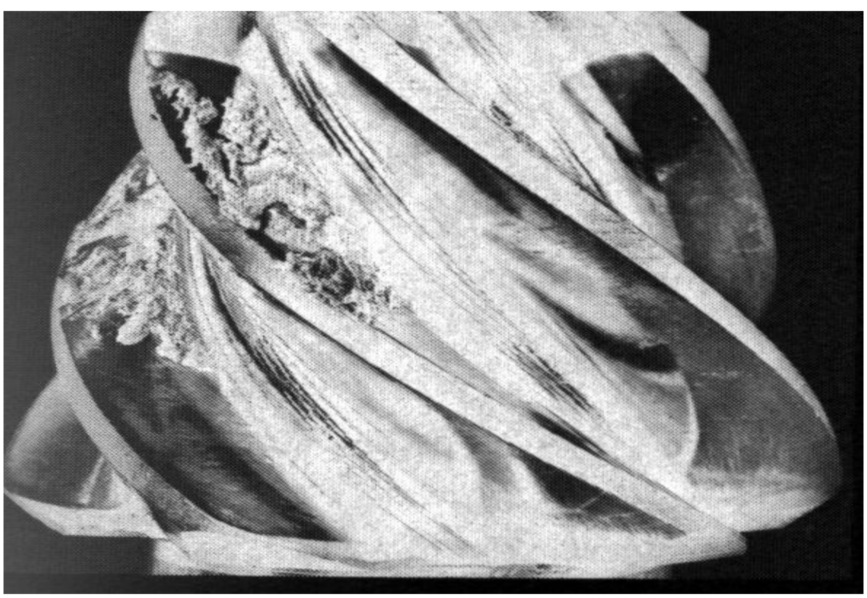
Health monitoring (condition monitoring) is already much practiced in many of today's engine rooms and plants, either by skilled engineers or diagnostic expert systems. However, techniques that rely on automatic pattern recognition have only recently been introduced into this field. Pattern recognition is a research area with a long-standing history, traditionally focused on finding optimal decision functions for static well-sampled classes of data. Besides issues encountered in any pattern recognition problem (feature extraction, small sample sizes, generalization), we face some special issues in health monitoring of rotating equipment. This requires the use of (relatively novel) methods for blind source separation, novelty detection and dynamic pattern recognition. We propose a *learning approach* to machine health monitoring that addresses these issues and investigate the usefulness of our approach in several real-world monitoring applications. First, we illustrate the problems connected to machine health monitoring with an illustrative every-day example.

Machine health monitoring: an example

Consider a rotating machine that is operating, for example a household mixer or a car engine. These machines produce a kind of noise that seems to be related to their rotating speed, e.g. putting the mixer in a faster mode produces noise at a higher frequency. A car engine is much more complex, since many vibration sources inside the engine contribute to the overall vibration and the engine has a larger and more complex mechanical structure. A car driver gets used to the machine sound during normal operation and may even be able to recognize the car when his or her better half is coming home from a day off. Of course, when cars get older the material wears and faults may develop inside the engine. These (incipient) faults can be recognized by the driver when he suddenly hears a strange noise among the familiar car noises. Initially, this may take the form of occasional clashes or ticks. An incipient fault with a low contribution to the spectrum may be masked by high-energetic frequencies due to other machine components like a water pump or a properly functioning gearbox. When the fault develops, a clearly distinguishable tone at some unfamiliar frequency can emerge. If the driver knows about car mechanics, he may try to remedy the problem himself. One way to diagnose the problem is to let the engine run and listen to the vibration inside, e.g. by putting a screw driver at the engine casing in order to track the relevant fault vibration source more closely.

After having diagnosed the problem, it may turn out that a minor disturbance was causing the strange noise, e.g. some dust entered the engine or a harmless bolt was Loosened a bit. Moreover, wear could have caused the structural characteristics to change over time. In this case, the driver would remove the dust, fasten the bolt, or just conclude that he had to cope with this slightly dissimilar sound until the yearly maintenance would be done at his garage. Noises of the type he had heard in this case are now stored in his “experiential database”, making it easier to spot the origin and its severity next time it appears. However, it can also be the case that there was a small problem with the lubrication and there was a small but growing imbalance present. At this stage, there was no reason for panic but it could lead to a potentially very dangerous situation: decay of bearings or gears. The driver should bring his car to the garage to look at the cause of the lubrication problem and e.g. rebalance the shaft. This is an expensive job, but the material damage that would have resulted from a car accident at the highway (let alone the human health damage) would be many times higher.





The previous example illustrates the purpose of health monitoring in rotating machines: detecting and diagnosing faults in an early stage, which may be feasible since many faults will manifest themselves as pure tones or strange noises in the overall machine vibration. The conventional approach would be to use many heuristics about the structural properties of the machine and look in the vibration spectrum for specific fault-related components with increased amplitude compared to previous measurements. This could be done either manually (the skilled operator) or on the basis of a rule-based system. It becomes immediately clear that in this approach one has to make large fault-databases for each new machine, since every machine vibrates in its own specific manner. Moreover, disturbances from nearby machines or irrelevant vibration sources along with ambiguities in the vibration spectrum may lead to situations that are not in the database, or wrongly assumed to be in the database. A frequency spectrum is often difficult to interpret because of the large amount of overlapping frequency components, structural resonances, modulating phenomena, noise influences, etc. present in the vibration spectrum

4.2 CONDITION BASED MAINTENANCE

Like all other efforts which require the expenditure of funds, electrical maintenance is changing.
Competition, costs, and equipment complexity have increased while budgets, operating margins, and maintenance staffs have decreased. As never before, the maintenance department must be able to show a positive effect on the "bottom line." Condition Based Maintenance (CBM) offers the promise of enhancing the effectiveness of maintenance programs in a way that no other single concept has ever matched. This relatively new approach to maintenance uses data drawn during operations and/or maintenance intervals to forecast the need for additional or future maintenance. It extends the concepts of predictive maintenance by using data from both on-line and off-line maintenance tests.

This reviews the classical approaches to maintenance and then compares and contrasts them with CBM. A variety of factors which affect the selection and performance of various maintenance alternatives are presented followed by an overview of the concepts and procedures involved in CBM. The intent is to allow readers to analyze the benefit that the technique might have on their maintenance program.

In addition to general updates, subsequent revisions have added descriptions of the analytical techniques that are being used or researched by companies which have adopted CBM. Sufficient detail is provided on the more promising mathematical techniques so that the reader may evaluate them for application to specific power systems

Breakdown Maintenance or Repair

Some would object to including this section as a maintenance concept. However, even today, many companies *choose* to "run it until it breaks". All too often we hear statements such as "We can't take that out of service." or "We've never had a problem so why bother to perform maintenance." Such an approach gambles that when a failure occurs, the resulting outage and repair costs will be less than the investment required for a preventive maintenance program. Surprisingly, breakdown maintenance does employ minimal preventive maintenance techniques. Lubricant levels, bearing and winding temperatures, load currents, voltages, power factors, and other such easily obtained data are measured; however, action is taken only when urgently and immediately required.

Some of the more common data items and how they are used in a breakdown maintenance approach. Notice that breakdown maintenance may not involve any data point analysis at all. Breakdown maintenance will be cost effective so long as no catastrophic failures occur. Of course, such an approach leaves the system open to major catastrophes because no precautions are taken to prevent them. This means that extremely hazardous conditions can exist with no way to predict them. Sadly, breakdown maintenance is the approach still used by far too many companies. The economic pressures mentioned earlier force organizations into a mistaken belief that running it until it breaks is the cost effective approach.

Preventive Maintenance

Preventive maintenance (PM) is currently the most widely accepted approach to maintaining electrical equipment. PM is a calendar based program in which very comprehensive test routines are applied to off-line equipment. Comprehensive test methods such as insulation resistance, power factor, protective device calibration checks, and circuit breaker time travel analysis, are used to evaluate current system conditions. Illustrates some typical data and briefly describes how they are used in the implementation of a preventive maintenance program. There are two very significant differences between the way the data are used in breakdown maintenance programs and preventive maintenance programs. In a PM program:

Data are collected during both on-line and off-line times. Off-line times are intentionally scheduled for the implementation of preventive maintenance procedures. Equipment which is discovered to need repair will be scheduled for outages to implement those repairs.

The principle problems with preventive maintenance programs are found in the financial department. Like life insurance, preventive maintenance programs cannot be economically evaluated except statistically. Consider a conversation that was overheard and reported by a student several years ago:

Preventive maintenance returns cannot be measured unless an unplanned and/or catastrophic outage occurs. When such an outage occurs, the value of a maintenance program can be compared directly to the cost of the outage. Such thinking is too philosophical for many financial officers, and so, preventive maintenance programs have an uphill battle all the way.

In spite of this difficulty, PM programs have become increasingly more common since the early 1950s. the widespread, good results have become too apparent to be ignored by all but the most Stubborn. Insurance carrier requirements are also moving many towards PM.

Predictive Maintenance

Predictive Maintenance takes advantage of proven cause_symptom_effect relationships to *predict* the need for corrective action. Consider dissolved gas analysis, for example. Industry experience has established limits for the amount and rate of change for combustible gases in insulating oil. Based on extensive analyses, we know that arcing is undoubtedly present in a transformer if the amount of acetylene rises above a certain concentration, or if its rate of production increases beyond a certain value. Thus if analysis shows that acetylene has exceeded these amounts, we can safely *predict* that arcing is occurring. Further, we can often predict how long the transformer has until failure. The transformer can be immediately scheduled for an outage, the cause can be isolated, and a repair can be implemented. Predictive maintenance is generally an equipment specific type of approach rather than a system wide strategy. That is, most facilities do not use predictive techniques throughout their system. Rather they will use equipment or specialty vendors to perform predictive procedures on their motors or transformers. Infrared scan is one of the few procedures that is performed on a system wide basis.

Three of the most common types of predictive maintenance procedures employed in modern power systems. Please note that the descriptions given are in no way intended to be rigorous. Rather they supply general knowledge as to how such programs work. The steps in a predictive maintenance program can be summarized as follows:

1. Key values are observed or measured.
2. These values are compared to norms for the equipment and potential problems are predicted.
3. Any equipment which falls outside of norms is scheduled for repair or re-testing.

Predictive maintenance methods are often incorporated into a preventive maintenance program. No outage occurs, repairs are scheduled, and major failures are averted. Predictive maintenance offers a very cost attractive maintenance alternative

Condition Based Maintenance

Condition based maintenance (CBM) has many similarities to predictive maintenance in that the data gathered during CBM intervals are compared to statistical norms—both averages and trends. CBM is more comprehensive than predictive maintenance since it uses both on-line and off-line test data. The principle benefit of CBM, however, is the manner in which data is used. Table 4 illustrates these principles. Test data is analyzed and future maintenance procedures on the equipment are determined by the results. The most significant difference between CBM and other types of maintenance is the equipment is in exceptionally good condition as indicated by the test results

THE NEXT SCHEDULED MAINTENANCE MAY BE SKIPPED ALTOGETHER FOR THIS EQUIPMENT!!

Since only a relatively small percentage of system equipment will exhibit problem test results at any one interval, it is reasonable to expect the overall maintenance effort to reduce drastically—perhaps to as little as twenty percent (20%) of pre-CBM levels. Such reductions are possible because only that equipment which is shown, by test data, to need additional servicing would be “on the list” for the next maintenance interval. Equipment that has been tested once every two years may now need attention only every five to ten years.

CONDITION BASED MAINTENANCE -- AN OVERVIEW

What is Condition Based Maintenance

CBM is a modern procedure which uses the condition of equipment to determine what, if any, testing and maintenance procedures should be performed. CBM is similar to a preventive maintenance program which includes an extensive array of predictive maintenance procedures. Note however, that predictive maintenance tends to be equipment oriented while CBM is system oriented. Equipment is maintained as usual including all normal tests as well as visual mechanical adjustments and inspections. Both on-line and off-line procedures are performed and test data are collected into a computerized data base. The test technician uses a notebook computer for this purpose. The data may be loaded by keyboard, or in some cases the test equipment will store the data directly.

The test results are initially reviewed by the technician performing the work. This review may be via statistical analysis software and/or by simple inspection and comparison. After the initial review, the data is uploaded to a central computer, where it is subjected to a more extensive review. The statistical analysis comprises two sections statistical averaging/comparison and trending. Describes the two methods and illustrates how they are used. Note that CBM relies heavily on the computer. Data collection, analysis, and storage; project tracking and scheduling, and report generation are the key elements which depend on the computer.

The Effects of Condition Based Maintenance

The use of a CBM program will blend perfectly with the five factors mentioned. Using a properly applied CBM program companies will increase the overall effectiveness of the maintenance program while decreasing overall costs. These are important considerations when evaluating a CBM system.

Required Equipment

Test equipment, computers, and software are the principle requirements for the implementation of a CBM system. Existing test equipment is sufficient for starting the CBM program; however, Upgrading to modern units which will readily interface with computers is strongly recommended. Notebook or laptop computers should be available for field test personnel. These will replace the pencil and paper approach to filling out test forms. Some existing test software has the ability to automatically save test results on disk; however, much improvement in these areas is expected in the next few years.

4.4 Oil Analysis

Oil analysis was originally used by the military and the railroad as a preventative maintenance program. It has expanded today to the field of study called Tribology. Oil analysis is used by industries from automobile shops to nuclear power plants. Each industry has its own specific needs and criteria for testing. It is important to understand that each industry has many different methods for testing and reporting. Industry is moving towards consolidation of methods, but there are still many differences that must be understood to be able to use the data presented.

It is the purpose of this course to give a clear understanding of the following:

- How to take a representative oil sample.
- How to the test are performed.
- How to interpret the data once you receive the report.

- How to cross reference data from one type of test specification to another.
- Other services are available to help in the solution of maintenance problems.

Sampling Procedures

Sampling technique is key to oil analysis. The sampling procedure can bias a sample to make it cleaner or dirtier depending on where or how the sample is taken. It is the goal of oil analysis to provide a representative insight into the actual condition of the oil and the condition of the piece of equipment.

It is important that the sampling be done in the following manner:

(a) When selecting a sampling point it is important to sample in several locations in the system to determine where the most representative sample can be taken. Some of the most common sampling ports are as follows:
(i) Reservoir (using a vacuum gun and tubing from the center of the reservoir).
(ii) In-line sampling port.
(iii) Before the filter.
(iv) After the filter.
(b) Take the sample while the system is operating if possible. If not, take it just after shut down.
(c) Be aware of airborne dust particles.
(d) Always close bottle as soon as possible, and be very careful where you place the lid when taking the sample.
(e) Make sure the system is warm when you take the sample.

Applying Oil Analysis

Oil analysis is the most widely accepted and implemented form of non-predictive maintenance technology. It is an integral part of the maintenance plan for power plants, manufacturing plants, trucking companies, construction equipment, aircraft, refrigeration system, processing and chemical plants, etc. Any piece of equipment that has a lubricating system is an excellent candidate for oil analysis. A successful oil analysis program requires an organized and sustained effort. Both the user and the laboratory must work closely together to achieve the desired results.

Determine the primary objectives: Oil analysis can be applied to equipment utilization, maintenance and management:

(a) Utilization
(i) Increase margins of operational safety.
(ii) Increase availability by decreasing downtime.
(iii) Increase overall component lifespan.
(iv) Control standby equipment and replacement part requirements.

(v) Decrease fuel and oil consumption.

(b) Maintenance

(i) Identify and measure tube contamination and component wear.

(ii) Eliminate unnecessary overhauls or inspections.

(iii) Reduce in-service failures and files repairs.

(iv) Establish proper lubricant service intervals.

(c) Management

(i) Improve cost assessment and control for equipment, labor and materials.

(ii) Improve equipment record-keeping procedures.

(iii) Evaluate equipment designs/applications.

(iv) Reveal faulty operator practices.

Almost any machine that has a lubricant system can be placed on an oil analysis program. Those components whose performance directly affects the continued operation of a particular unit or overall profitability of business are the most likely candidates for routine oil analysis.

Oil Analysis Testing

Testing Procedures: Oil analysis is the evaluation of the oil itself and any contamination that is present. The information derived from the following test looks for different types of wear and contamination. Each test looks at a different aspect of the oil. This is the reason for the different tests. The tests are as follows:

(a) Physical Testing

(i) **Viscosity:** The viscosity test measures the thickness of the oil. The oil is heated and run through the viscosity bath. The results are then compared to the new oil specification. This test is valuable in determining the condition of the oil and is an indicator of water contamination and oxidation.

(ii) **Water content** (greater than 1%): Water above 1% is detected in the basic oil analysis

(b) Petrochemical analysis: Petrochemical analysis is the analysis of the metal content and additive package. This test checks 19 elements of the chemical spectrum and reports them in parts per million. These numbers represent the elements less than 5 microns in size. The spectrometers design limits its detection level to 5 microns and below. To evaluate the particulate larger than 5 microns, other test methods must be implemented.

The petrochemical analysis is used to look for bearing or bushing wear in the form of copper, lead or tin. The petrochemical analysis also looks at dirt levels in the form of silicon. Wear in pumps, housings and other points of contact can be evaluated using the information. It is important to remember that these are small particulate and even if there are large particles of metals in the oil, larger than 5 microns, the petrochemical analysis will not detect them. The larger particulate will be detected in the particle count or the filter analysis, if the particulate are large enough.

The additive package of the oil can be identified and evaluated using the petrochemical analysis.

(c) Particle analysis: The particle count is the single most important part of the report to measure the efficiency of system filtration. The particle count measures all particulate in the oil larger than 5 microns. Particulate include dirt, carbon, metals, fiber, bug parts, etc.

The particle count can be done using either laser or optical methods. The laser method reports the quantity, size and distribution of particulate but not what they are. The optical method gives a quantity, size, distribution and identification. A combination of these two methods can provide the most representative analysis available.

The color photograph that is taken of the 0.8 micron filter patch gives a visual identification of the contamination. This is one of the most effective tools for showing system cleanliness.

(d) Other Tests: Other tests are needed is some situations. For example, some systems have a low tolerance to water content or acidity levels. Additional testing is required in these situations. The following is a brief description of additional test and the information they provide:

(i) **Water by Karl Fisher-ASTM-D1744:** This test measures water content down to 50 parts per million and is 0.005%. It is used in turbine system analysis, servo systems and any other system that has low tolerance for water.

(ii) **Total Acid Number-ASTM D-644:** This test measures the acidity level of a system. Over time the acidity level of the system increases. This can be detected with this test. In addition, some forms of contamination can also increase the acidity levels.

(iii) **Foam Test-ASTM D-892:** In some systems high amounts of carbonization of oil occurs and pump cavitations is a problem. In these cases the oil could be foaming and causing these characteristics. This test measures the ability of the oil to resist foaming when air is injected into the oil in a controlled environment. In many instances the problem once identified can be corrected by changing to a different type of oil.

(iv) **Flash Point-ASTM D-3828:** Each oil type has known flash point when it is produced at the refinery. In some situation, contamination such as solvents, fuels or other flammable substances are present in the system. This test in an indicator of this type of contamination. The procedure uses the new oil flash point as a base line, for example 525°F. If the sample in question has a flash point of 250°, then the oil could be contaminated with a flammable substance.

(v) **Infrared analysis:** In many situations the customer is looking for the source of external contamination. This is initially discovered by a high particle count or short filter life. In some cases, the contamination is due to a cross contamination of fluids. In this case, a footprint of the new oil is taken and it is overlaid with the footprint of the oil in question to determine if there is cross contamination. In addition to cross contamination situation, this test can also give information on oxidation, nitration, water content and sulphur levels.

Particle Analysis

Particle analysis is the second phase of oil analysis. This test evaluates the particulate from 5-100+ microns. A particle count is a totally separate test from a petro analysis. Particle analysis is one of the most misunderstood procedures in oil analysis.

It is the purpose of this section to give a clear understanding of what particle tests are available, different formats of information, and how to interpret the data.

Two of the most common methods of particle counting are:

(a) **Automated Mechanical Method:** The most common method is the automated mechanical method. This method employs a particle counting machine that uses some form of laser beam or light source to count the particulate.

Advantages

- Easy to perform.
- Requires limited technician training times.
- Provides automatic graphing capabilities.
- Fast.

Disadvantages

- Cannot count samples with high water content.
- Some use high dilution factors that decrease accuracy.
- No identification of particulate composition (What type of particle is it?).
- Photograph of contamination is not possible.

(b) **Manual Optical Method:** THIS METHOD IS A MANUAL THAT FOLLOWS Aerospace Recommended Practice ARP 598. In this method 50-100 m/s of fluid is filtered through a 0.8 micron guided Millipore patch. The particulate are then counted and identified using a high power microscope.

Advantages

- Can count samples with high water content.
- Uses little or no dilution factor to increase accuracy.
- Identifies the type of particulate.
- Photographs of contamination are possible.

Disadvantages

- Requires highly trained staff.
- No automated graphing system.

- Time consuming.

Advantages of Oil Analysis

- Quality service.
- Low cost investment tool.
- Provides a service history of individual equipment.
- Improves equipment reliability.
- Highlights minor faults before they become major problems.
- Reduces expensive parts replacement.
- Reduces maintenance and servicing costs.
- Extend oil change intervals.
- Reduce new oil costs.
- Reduce waste oil costs.
- Monitors positive and negative results.
- Allows you to schedule downtime and increase productivity.
- Test machinery before purchase.
- Increase machinery resale value.
- Help the environment.

4.5 Vibration Analysis

Vibration analysis is used to detect the flaws in their early stages that can cause machine failure in future. It allows machine to be repaired or replaced before an expensive failure occurs. Using the latest and most innovative technology in computerized data reduction and analytical equipment, a Periodic Machinery Vibration Monitoring and Analysis Program have been developed. This program provides a regularly-scheduled vibration monitoring of rotating machinery to establish trends and identify trouble spots, which are:

1. Worn and damaged bearing.
2. Worn and damaged gear.
3. Lubrication problem.
4. Misalignment.
5. Out of balance.
6. Loose fitting of foundation.

Vibration analysis allows the maximum interval between repairs to be realized through monitoring the actual mechanical condition of a piece of rotating machinery. Equipment downtime is not required for monitoring activities to occur. The monitoring, in turn, directly minimizes the number and cost of unscheduled machine outages created by component failures. Hence, optimum equipment availability may be obtained. Vibration analysis is predicated on three basic facts:

- Evaluating current machine condition.
- Diagnosing faults associated with operational machines.
- Monitoring and trading the overall condition of machine`s overtime.

Monitoring the vibration from machinery can provide a direct correlation between the mechanical condition and recorded vibration data of each machine. Vibration analysis can be used to identify specific degrading machine components or failure modes of machinery before serious damage occurs.

Vibration Basics

To begin a discussion on vibration analysis, it is important to understand that the location of a vibrating body`s surface is called a vibration or oscillation. The swinging of a pendulum and the motion of a plucked guitar string are typical example of vibration. The theory of vibration deals with the study of oscillatory motions of bodies and the forces associated with then. A vibration system must, in general, include a means for storing potential energy (spring or elasticity), a means for storing kinetic energy (mass or inertia), and a means by which energy is gradually lost (damping or resistance).

Vibration Measurement

A vibration transducer (sensor) is attached (or held by hand) to vibrating surface during vibration measurements. The vibration sensor converts this mechanical motion into an electrical signal that corresponds to the body`s motion in space. The vibration analyzer is then used to sample this electrical signal and make various calculation based on the electrical signal`s properties.

Working of Vibration Analysis

(a) Initial Setup

(i) Develop a route schedule, including a sketch indicating the bearing data points of the equipment to be included in the program.

(ii) Mark data collection points on machinery to sure continuity on all future inspection. These will correspond with data points indicated on sketch which will be a part of the machine report.

(iii) Collect all relevant machinery information such as: type of machine, bearing type, size, number of balls etc., as well as gear size/number of teeth, motor, shaft speed, machine operating condition (i.e., constant speed-constant load, constant speed-variable load etc.).

(iv) Program machinery database into computer, including alarm set points and special information.

(v) Collect initial vibration data.

(vi) Process and analyze vibration data and submit initial report of findings conclusions and recommendations.

(b) Periodic Data Collection

(i) Collect machinery vibration data.

(ii) Process and analyze vibration data and submit report of findings, conclusions and recommendations. The reports include, but are not limited to:

- A summary report on each machine, containing the conclusions and recommendations based on vibration and spike energy amplitude, spectrum analysis, and any additional analysis performed on site (i.e., phase analysis mechanical measurement etc.).
- An alarm report showing all the measurement points which exceed the predetermined alarm set point and the percentage over the alarm level.

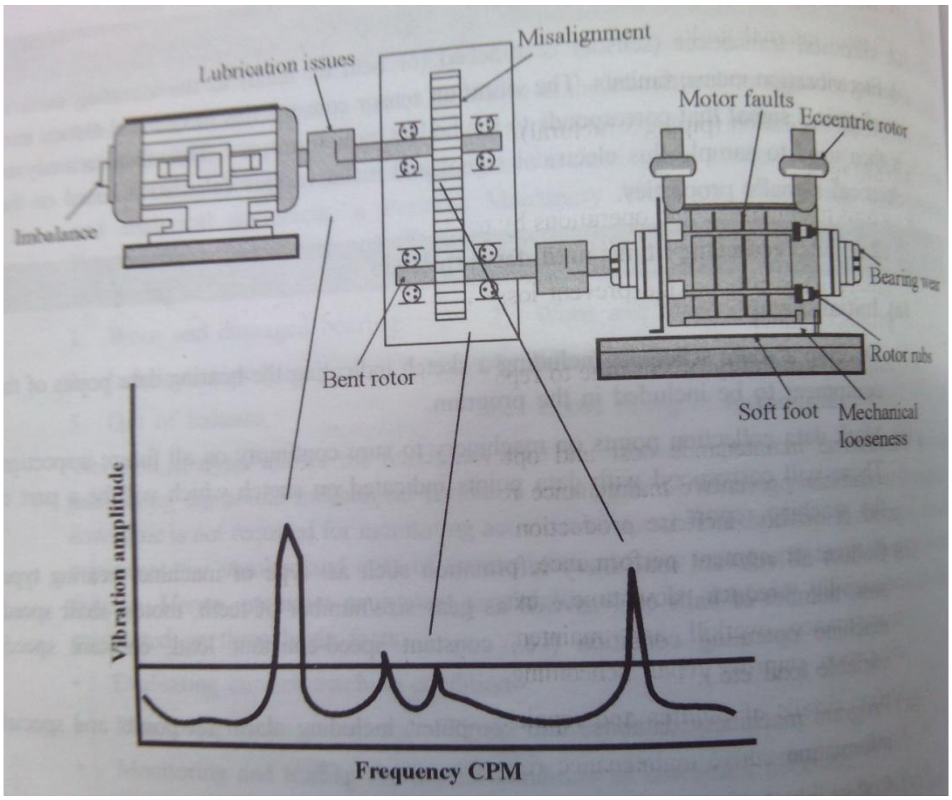


Figure - Vibration Analysis

Assets in Vibration Analysis Technique

(a) Rotating equipment such as motor, pumps, blowers, fans, gear boxes, mills, rollers, crushers, compressors and turbines.

(b) Interconnected structures, static equipment and piping.

Equipment Problems Detected During Vibration Analysis

(a) Unbalance

(b) Misalignment

(c) Looseness

(d) Bent shaft
(e) Gear problems
(f) Bearing problems
(g) Motor internal faults
(h) Electrical grounding faults
(i) Noise excitation (piping/structural)

Advantages

- Focus maintenance and operations by predicting functional failures, forecasting failure mode and estimating time until failure; conveniently schedule targeted proactive failure interventions and prevent loss of production availability/production capacity/product quality.
- Improve reliability (mean time to repair, mean time between failure, plant availability and utilization).
- Decrease maintenance cost and optimize returns, reduce labor and material cost needed for preventive maintenance routines, minimize energy consumption, increase product quality, increase production capacity, reduce spare parts inventory, provide consistent equipment performance, provide reliable production, increase equipment availability reduce downtime, extend asset life, reduce overhauls, prevent maintenance overkill and maintenance collateral damage, improve staff time allocation, improve repair scheduling, save overtime cost.
- Define details of failures and repair requirements.
- Optimize preventive maintenance routines.
- Avoid health and safety and environmental risks.
- Determination of the dynamic behavior of machine section.
- Determination of the mechanical condition of machine.
- Determination of the feasibility of a possible capacity increase.
- Most cost-effective implementation of rebuilds.
- Prediction of future mechanical problems and reduction of unplanned shutdowns.
- Scheduling of service action based on prioritized maintenance recommendations.

Areas of Application for Vibration Analysis

(a) Power generation as well as cogeneration, windmills and turbines.
(b) Oil and gas extraction, refining, processing and transmission.
(c) Mining.
(d) Heavy primary industry and general manufacturing.
(e) Pulp and paper.

4.7 EQUIPMENTS USED IN MACHINE HEALTH MONITORING

1. **Accelerometers:** Accelerometers and accessories are used for measuring responses in a vibrating medium like motor and machinery, bearing associated cables and other instrumentation bearing accessories.
2. **Impact and Impulse Hammers:** These are used for carrying out model testing of structures as well as for detecting defective structural items, Light meters.
3. **Paperless Recorders:** These are used for recording responses like oscilloscopes and FFT analyzers.
4. **Vibration Analyzers:** These can be used to perform a series of tests that will provide the specific sources of vibration. Shock pulse meters and seismic meters are also used.
5. **Ultrasonic Tester:** Used to measure thickness of plates and ultrasonic leak detectors to detect leaks.
6. **Data loggers** and embedded software for recording continuous data such as vibration responses and sound levels.
7. **Laser instruments:** Used for alignment verification and precision alignment.
8. **Stroboscopes** for speed measurement and for balancing of rotating machinery.
9. **Infrared imaging cameras:** For getting relative temperature contours in a system.
10. **Motor motoring and testing:** For continuously monitoring the motor conditions at load as well as at no load and to take corrective action.
11. **Tachometers** for speed measurement.
12. **Infrared thermometers** for measuring temperature in a furnace or a head object.
13. **Transmitter,** power amplifiers for electronic signal processing.
14. **Humidity meters:** To measure the humidity.
15. **Oil analysis spectrometers** For evaluation the extent of metallic particles in the fluid. Other technique such as visa costing, dilution measurement, water level indicators and particle measuring devices indicates the contamination in different applications.
16. **Power measurement equipment** such as energy meter and power factor measuring instruments.
17. **Gas leakage detector:** Gas leakage detection in refineries and gas bottling plants.
18. **Acoustic emission analysis:** Used for detection of crack growth through piano electric crystals.
19. **Magnets inductive cable tester** used for shallow subsurface cable defects.
20. **Eddy current transducers:** These directly observe the rotating shafts to measure the radial (and axial) vibration of the shaft. The level of the vibration can be compared with historical baseline values such as former start ups and shut downs, and as load changes to assess the severity.
21. **The shock pulse method (SPM)** is the only successful monitoring technique specializing on rolling element bearings by determining accurate information on:

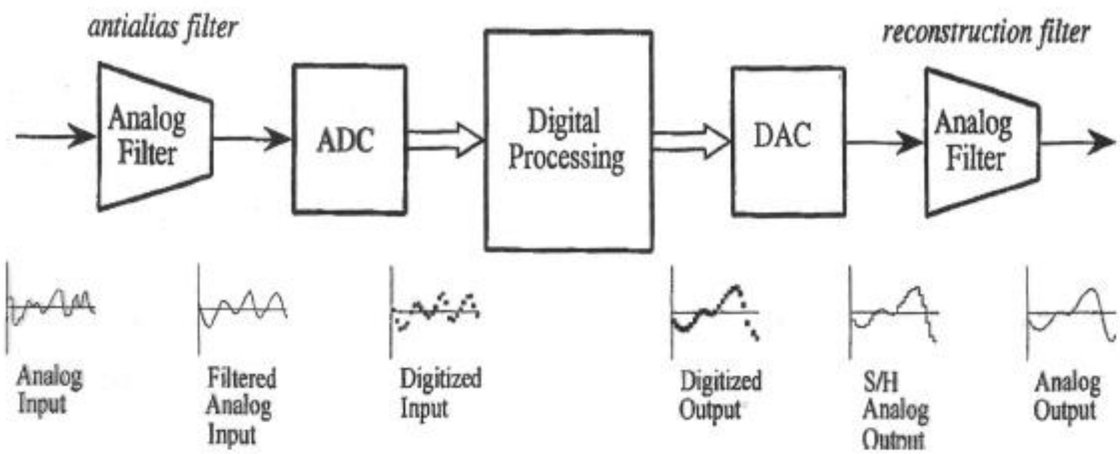
(a) The mechanical state of the bearing surfaces.
(b) The lubricating condition throughout the bearing life time.

4.9 Digital signal processing (DSP) is the mathematical manipulation of an information signal to modify or improve it in some way. It is characterized by the representation of discrete time, discrete frequency, or other discrete domain signals by a sequence of numbers or symbols and the processing of these signals.

Digital processing of analog signals proceeds in three stages:

1. The analog signal is digitized, that is, it is sampled and each sample quantized to a finite number of bits. This process is called A/D conversion.

2. The digitized samples are processed by a digital signal processor
.
3. The resulting output samples may be converted back into analog form by an analog reconstruct or (D/A conversion).
A typical digital signal processing system is shown below.



4.10 RELIABILITY DATA: ACQUISITION AND ANALYSIS

Data analysis involves organization of data for specific components or subsystems and identification of their failure events and rates. Data acquisition includes identifications and description of the system and, subsequently, collection of operating and maintenance experience data, and test description and results.

Planning a data-Collection Program me

The advantage of acquisition and accumulation of data is that these can be used to predict the reliability of a component when it is operated under the conditions which these data represent. In planning a program me to collect data, due consideration should be given to the several factors that are important to the success of the program me:

1. A complete set of clearly stated technical objectives must be established.
2. The methods by which the required data will be collected and processed should be stated.
3. A detailed written document which is in effect a specification for the work to be done during the study must be prepared. This specification should normally contain:

(a) A brief and factual account of the development and objectives of the reliability program me,
(b) Explicit definition of terms that are of interest to the study and that are used throughout the specification,
(c) Data requirements, such as item of data, criteria, unit of measurements, etc.,
(d) A complete and detailed technical inventory of the product to be evaluated, and
(e) Materials and facilities needed for the evaluation.

Analysis and Reporting

As failure forms are received they are reviewed, and completed by a member of the reliability group. This person should have a good understanding of the complete system so that he is able to judge the consequences of a failure with respect to the system and establish it critically. He should also be able to initiate the necessary corrective action.

Reporting represents one of the reliability group's greatest responsibilities. It furnishes all levels of engineering activities and management with information relevant to their needs. Consequently, the possibility of misinterpretation must be minimized. Answers to questions such as the following should be available in the reporting:

1. Were the data taken from the development tests, field tests, component tests, system tests?
2. What were the environmental conditions?
3. Were the data homogeneous and representative?
4. How large was the sample size?
5. What assumptions were made concerning the shape of the failure distribution?

Data-acquisition Methods

Two methods are usually employed in collecting the required data, depending upon the relative importance of accuracy vs cost.

Method 1 The second method is to employ technical personnel who have the assigned responsibility for carrying out the measurement program me. This method has numerous advantages. A few important ones are enumerated below:

1. Personnel concerned can be given a thorough understanding of the objectives of the study.
2. A high interest in the study can be maintained at the source of the data.
3. As a result of (1) and (2), the evaluation personnel can make the necessary decisions to keep the study on the right course.
4. Data supplied under the conditions of close monitoring and recheck require a negligible amount of rework and interpretation before final processing.
5. Selective attention can be given to developing details or trends that are pertinent to evaluation.
6. Inconsistencies and errors in the data can be detected through cursory checks and analyses.

Method 2 The first method is to supply the operational, maintenance, and production personnel with what are known as “data forms” or “failure forms” containing blanks for the desired information, and ask that forms be completed as directed. Forms containing the raw data are returned to a central collection point (reliability group) for processing. The method has the advantage of low cost but the data so collected are invariably of questionable accuracy and completeness. The operational, maintenance, production personnel, in general, tend to look upon data collection as mere paper work, and in the press of more urgent responsibilities they tend to neglect it.

Use of Samples

Since it is seldom feasible to make measurements on the entire population, the use of statistical techniques is necessary. Such techniques permit the extrapolation of the results obtained from a sample to the population as a whole and therefore to other similar populations.

The use of samples in the measurement of reliability requires that the final result be presented as an estimated value with the confidence limits to indicate the probable range within which the population mean will fall. The larger the size of the sample, the narrower will be the confidence interval.

Data Management

A data management system needs to be established for the purpose of collection and evaluation of reliability data from equipment manufacturers and users. The important tasks of the data management would be:

1. Collection and analysis of in-plant or field data, test data, and manufacturer`s data, and
2. Classification of the collected data by equipment and event types in order to facilitate evaluation and correlated of data.

A breakdown of functions required in data collection and classification is shown in Fig.. Sample failure data collection and analysis forms are shown in Appendices 12A and 12B.

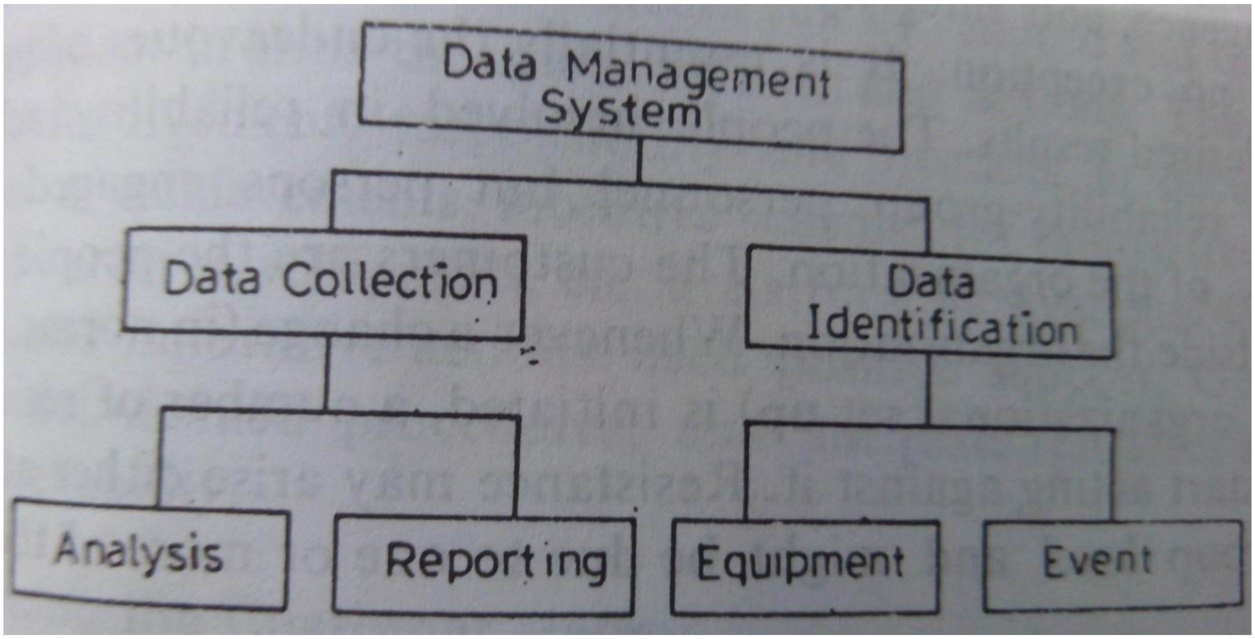


Fig. Data management system

Data Bank

A reliability data bank is an integral part of a reliability group. It usually consists of :

1. An event store, and
2. A reliability data store.

It serves the following two main purposes:

1. It provides information to its contributors regarding the performance (availability, reliability, etc) of their own plant, and
2. It provides the generic reliability data required by the project analysis section of the reliability group.

The functional relationships of the data-bank system are depicted in Fig.

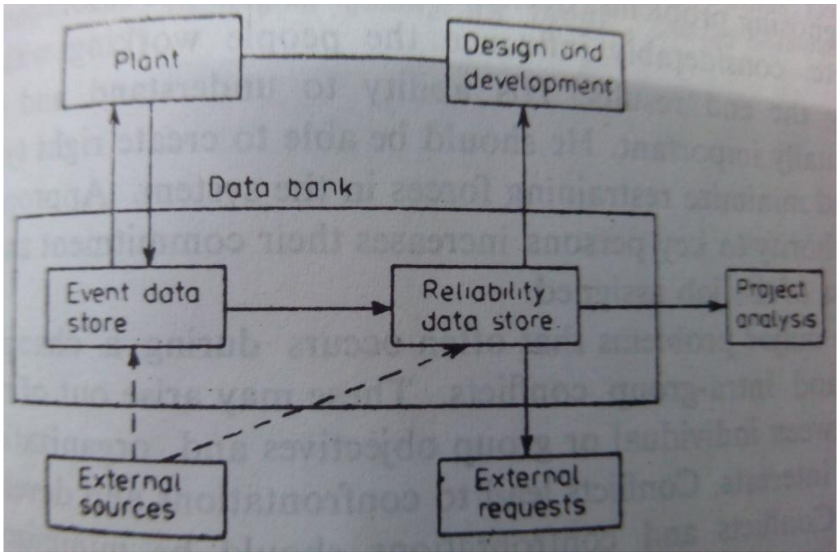


Fig. -Data Bank

4.11 What is an Intelligent System?

It is a concept It is a System that exists It learns during its existence It senses its environment and learns - for each situation, which action enables it to reach its objectives It continually acts, mentally and physically or externally By acting it reaches its objectives

It is autonomous in the sense that it decides its intermediate objectives (to reach its original objectives) and plans its actions to reach those objectives, evaluate the consequences of its actions (by sensing the environment and judging whether it is a desirable/ expected state)
The actions are deliberate than by chance It consumes energy and uses it for its internal processes, and in order to act its actions modify the environment what does this definition simply

The system has to exist.
An environment must exist, with which the system can interact. It must be able to receive communications from the environment, for its understanding of the present situation.

It must be able to process the sensed information and build the model of the environment. It must be able to abstract the communications received by the senses the communications, in turn, need an interchange of matter or energy. This communication is for the purpose of transmitting information or for the specific purpose of structuring of matter in the environment (that the system perceives).

The IS must have an objective whether given or set by itself. Capable of setting its objective consistent with its original objective. It must be able to check (or aware) whether its last action was favorable or has desired impact on the environment or whether it resulted in getting nearer to its objective, or not.

To reach its objective it has to select its response. A simple way to select a response or an action is to select one that was favorable in a similar previous situation. But it may have to reason it out in new situations

Finally, it must be able to act; to accomplish the selected response. It must be able to learn. Since the same response sometimes is favorable and sometimes fails, it has to be able to recall in which situation the response was favorable, and in which it was not. Therefore it stores situations, responses, and results. it must be able to act; to accomplish the selected response.

It must be able to learn. Since the same response sometimes is favorable and sometimes fails, it has to be able to recall in which situation the response was favorable, and in which it was not. Therefore it stores situations, responses, and results.

- Where do we need Intelligent systems

- Intelligent Systems (methods) are used in science and industry with a wide variety of applications involving the following areas: intelligent robotics, health monitoring applications, speech and language interfaces, financial forecasting and prediction, internet and agent technology, image processing, planning and scheduling, knowledge-based systems, security and fraud detection

  It gives us
- Parsers, theorem proves, inference engines
- Tools – searching, classification, statistical, pattern matching, abstraction, translation
- Tools – problem solvers, game playing, modeling, robotic guidance
- Technologies – neural networks, knowledge acquisition, expert systems, planning, dialogue generators
  The above are integrated into General purpose applications

  Intelligent systems – Examples Smart dwellings, Smart space, Smart vehicles, Intelligent ground, underwater, space exploratory vehicles Cave busters, Humanoid robots, Pilot-less plane Smart manufacturing plants Smart security devices campus security, access to classrooms and labs attendance, entry control, switching off devices, Vehicle/individual movement an tracking, surveillance Smart SW to locate other SW At what stage do we call a system intelligent system

4.12 The Importance of Good Database Design

A good database design is crucial for a high-performance application, just as an aerodynamic body is important to a race car. If the car doesn't have smooth lines, it will produce drag and go slower. Without optimized relationships, your database won't perform as efficiently as possible. Thinking about relationships and database efficiency is part of *normalization*. Beyond the issue of performance is the issue of maintenance your database should be easy to maintain. This includes storing only a limited amount (if any) of repetitive data. If you have a lot of repetitive data and one instance of that data undergoes a change (such as a name change), that change has to be made for all occurrences of the data. To eliminate duplication and enhance your ability to maintain the data, you might create a table of possible values and use a key to refer to the value. That way, if the value changes names, the change occurs only once in the master table. The reference remains the same throughout other tables Understanding the Database Design Process

In this chapter, you'll learn the thought processes behind designing a relational database. After this theory-focused chapter, you'll jump headlong into learning the basic MySQL commands in preparation for integrating MySQL in your own applications.

. Some advantages to good database design
. Three types of table relationships

. How to normalize your database
. How to implement a good database design process
The Importance of Good Database Design

A good database design is crucial for a high-performance application, just as an aerodynamic body is important to a race car. If the car doesn't have smooth lines, it will produce drag and go slower. Without optimized relationships, your database won't perform as efficiently as possible. Thinking about relationships and database efficiency is part of *normalization*. Beyond the issue of performance is the issue of maintenance your database should be easy to maintain. This includes storing only a limited amount (if any) of repetitive data. If you have a lot of repetitive data and one instance of that data undergoes a change (such as a name change), that change has to be made for all occurrences of the data. To eliminate duplication and enhance your ability to maintain the data, you might create a table of possible values and use a key to refer to the value.

That way, if the value changes names, the change occurs only once in the master table. The reference remains the same throughout other tables For example, suppose that you are responsible for maintaining a database of students and the classes in which they're enrolled. If 35 of these students are in the same class, let's call it *Advanced Math*, this class name would appear 35 times in the table. Now, if the instructor decides to change the name of the class to *Mathematics IV*, you must change 35 records to reflect the new name of the class. If the database were designed so that class names appeared in one table and just the class ID number was stored with the student record, you would have to change only 1 record not 35 to update the name change. The benefits of a well-planned and designed database are numerous, and it stands to reason that the more work you do up front, the less you'll have to do later. A really bad time for a database redesign is after the public launch of the application using it although it does happen, and the results are costly. So, before you even start coding an application, spend a lot of time designing your database. Throughout the rest of this chapter, you'll learn more about relationships and normalization, two important pieces to the design puzzle.

Table relationships come in several forms:
. One-to-one relationships
. One-to-many relationships
. Many-to-many relationships

For example, suppose that you have a table called employees that contains each person's Social Security number, name, and the department in which he or she works. Suppose that you also have a separate table called departments, containing the list of all available departments, made up of a Department ID and a name. In the employees table, the Department ID field matches an ID found in the departments table. You can see this type of relationship. The PK next to the field name indicates the primary key for the table. In the following sections, you will take a closer look at each of the relationship types.

REVIEW QUESTIONS

Q.1. What is meaning by machine health monitoring and where it is used.

Q.2. Explain the term condition based maintenance.

Q.3. Explain the oil analysis with suitable example and their use.

Q.4. Give the signature of vibration, noise and thermal.

Q.5. Explain the instrumentation & equipment used in m/c health monitoring.

Q.6. Give the term of data acquisition and analysis with suitable example.

Q.7. Explain the application of intelligent system.

Q.8. Explain data base design.