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Condition Monitoring Program: A Need to Improve Performance of Machineries

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ABSTRACT
The machine can talk, but it speaks in its own language. It communicates in the form of vibration. Imbedded in that vibration signal are all the internal defects of the machine. It is telling us about itself. All we have to do is listening. Sometimes, we need a translator. That is what the measuring instruments, especially FFT spectrum analyzer does. It translates the complex vibration signal coming from the machine into something that we, humans can understand. In machine diagnostics, we are playing the role of a machine doctor, which is not much easy task. Vibration signals are a major source of information available from the machine itself for fault detection and diagnosis. All factors should be considered, along with machine's history, in any good diagnostic efforts. We are always looking at the effect to try to find the cause. This paper focuses on the understanding of machinery monitoring, sources of vibrations and. This paper tells us how to increase life of machine by arranging program of vibration monitoring and what are the precaution should be taken while analyzing any machine.

Keywords
Fast Fourier Transform, vibration monitoring, transducers, misalignment, imbalance

1. INTRODUCTION
Vibration of mechanical equipment is generally not good. It causes excessive wear of bearings, it causes cracking, it cause fastened to come loose, it causes noise and it is generally uncomfortable for human. Thus the program of regular vibration monitoring should arrange to reduce adverse effects. The operating machine is talking to us in its own language telling us all about its internal condition. We would listen and interpret what it is saying. This is where instruments are used. A machine's vibration signature is like a heartbeat. A vibration analyst performs the same diagnostic service on machinery that a medical doctor performs on a human patient. There are generally two situations in which vibration measurements are taken. One is in a surveillance mode to check the health of machinery on a routine basis. The second situation is during an analysis process where the ultimate goal is to fix a problem. In both situations, there are several types of instruments available to take the measurements and at least as many ways to acquire the data. The instruments, however, faithfully and consistently measure the physical quantities of vibratory motions, but they display it differently. There are so many instruments used to measure vibration tremendously in the past 20 years. Among all these modern instruments, Fast Fourier Transform (FFT) is widely used which represents state of the art in vibration measurements

2. SOURCES OF VIBRATION
The sources of all machine vibration are less than perfect design and perfect manufacturing. In other words, defects are the sources of vibration. A perfect machine would generate no vibration when operating. Perfection is not achievable at any cost, and just approaching perfection becomes expensive. Therefore, we need to always coexist on this planet with defects. Every vibration problem is first a problem in identifying and locating source. Identifying source means to perform frequency analysis to tag the offensive frequency, and then locate the source by tracking the frequency to its origin. The amplitude is then measured to judge the severity. These typical problems have accounted for 98% of all past and known vibration problems. There are many sources from which vibration problem occurs like imbalance, misalignment, bearing, etc.

2.1 Imbalance
Mass imbalance is at the top of the list because it is the most common cause of vibration and easiest to diagnose. Imbalance is a condition where the centre of mass is not coincident with the centre of rotation. Following figure shows such type of condition.

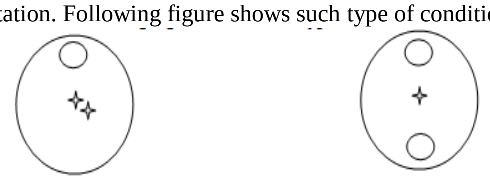

Fig. 1: (a) Out of balance (b) In balance

This can be viewed as an imaginary heavy spot on the rotor. The heavy spot pull the rotor and shaft around with it causing a deflection that is felt at the bearings. The task for the balance is to find the amount and location of the heavy spot and apply an equal and opposite weight (180˚) to compensate. This will bring the centre of mass to be coaxial with the centre of rotation, and the result is a smooth running rotor.

Following are the causes of imbalance:

- Porosity in casting.
- Non uniform density of material.
- Manufacturing tolerances.
- Machining
- Maintenance actions like changing bearings or cleaning, etc,
- Couplings

2.2. Misalignment
Coupling misalignment is a condition where the shaft of the driver machine and the driven machine are not on the same centre line. Non coaxial condition for misalignment may be parallel or angular misalignment. Parallel misalignment is as shown in figure 2.

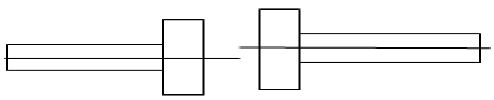

Fig. 2: Parallel misalignment of two shaft

Since it is impossible to get the output shaft of one machine perfectly aligned to the input shaft of the driven machine, flexible couplings are available to take up the misalignment. Flexible coupling helps the two machines to operate, but not necessarily smoothly. For the perfect alignment, there is more strain on the couplings. This strain causes a higher level of vibration. It also causes the bearings, seals and couplings to wear faster. Also if you are going to change bearings, seals or couplings frequently, it is likely that misalignment problem occurs continuously.

2.3. Bearings

Bearings are the most important machine components which create vibration problems. To be able to monitor bearings is the reason that most vibration analysis problems are started. 90% of bearing failures can be predicted months beforehand. Being able to predict 90% majority is a good enough reason to invest in a bearing monitoring program for many companies. Bearings fail for several reasons, the least of which is a manufactured–in defect. All bearings have some defects and they are graded accordingly. It is only a matter of degree of defects that separates out the highest quality of bearings from lowest quality ones. The primary causes of bearings failure are:

- Contamination including moisture
- Lack of lubrication
- Overstress
- Defects created after manufacturing, etc

2.4 Motor Vibration

Every electrical machine including all ac motors and power transformer cause mechanical vibration. Vibrations due to electrical problems can be easily determined by disconnecting electric power to the machine and seeing vibration immediately disappears or gradually winds down. An abrupt decrease in vibration upon power disconnection indicates an electrically related vibration. If this vibration remains high and gradually decreases as the motor spins down, a mechanical cause due to rotation is indicated possibly imbalance, misalignment or bearings.

2.5 Looseness

Looseness is another factor to cause mechanical vibration. Looseness means mount or place any one or more components like gears, pulleys, flywheels, etc on any other machine components like shaft, beam, etc using keys, nuts and bolts, couplings. If they are not connecting tight accordingly, they will create noise or mechanical imbalance which causes mechanical vibration. Thus before operating, please check whether, they have tightened or not as per requirements.

3. INSTRUMENTS

To measure the vibration parameters, there is a need of sensible instruments. There are many instruments such as Transducers, Stroboscope, Oscilloscope, Tape Recorder, FFT Analyzer, etc.., are used to measure vibration parameters. FFT Analyzer is the most accurate and effective analyzer to measure vibrations in the system.

3.1 FFT Analyzer

FFT Analyzer has been available only during last decade. FFT means Fast Fourier Transform Analyzer. All the other instruments that have discussed were analog instruments i.e. they processed the signal itself. By contrast, the FFT analyzer first digitizes the input signal, and then performs all subsequent operations digitally on numbers. This introduces some errors but it makes the display in the frequency domain much faster. An FFT analyzer acts as a parallel filter analyzer but with hundreds of filters.

3.1.1 Why FFT Analyzer?

There are at least three good reasons looking for FFT which gives frequency domain

1. First, specific defects show up as specific peak. I prefer to use the term defects because a perfect machine would generate no vibration, and both time and frequency domain would be straight lines. This correlation of peaks to defects is crucial to successful analysis and is not easily accomplished in the time domain.
2. Second, surveillance measurements are best done in the frequency domain. An overall number can be assigned and trended.
3. Third, small signals are not hidden in the frequency domain. It is difficult to see a small amplitude sine wave riding on top of a large amplitude sine wave on an oscilloscope display, but in the frequency domain, it shows up as a definite peak. The result is that mechanical defects can be seen when they are still small tracked as they progress. Small vibrations can be clearly seen and measured in the frequency domain in the presence of large vibrations. For example, a small gear defect can be seen on a machine with large motor imbalance and bearing noise presence.

3.1.2 Working of FFT Analyzer

Following figure is a simplified block diagram of an FFT spectrum analyzer. This diagram shows that the input waveform, a simple sine wave, in this case, is first amplified, then put through an anti alias filter, which is a low pass filter. A time block of data is captured and held in the sampling process while an analog-to-digital (A/D) converter digitizes the data. In digital form, it can be displayed as a time waveform or further processed into a frequency spectrum. To accomplish the latter, a window function is applied to remove errors, the FFT transformation is done, and the resulting data can be displayed in the frequency domain.

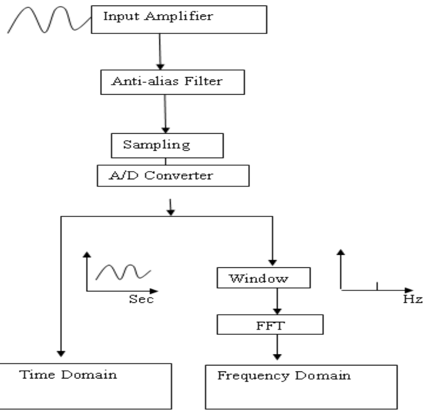

Fig 3: Block diagram of FFT

3.1.2.1 Anti-Aliasing Filters

By varying the flash rate slightly in stroboscope, you can make the motion move forward and backward in slow motion as discussed earlier. This is the phantom image of low frequency data due to high speed motion when measuring speed is too slow. This is an example of aliasing. To overcome this aliasing, low pass filters are applied to the input waveform to remove high frequency data that could cause phantoms. These are called anti alias filters.

3.1.2.2 Sampling

The analyzer cannot perform the Fourier Transformation continuously. It has a dedicated internal computer that is very fast to perform these calculations, but it must look at a time block of data. This is due to the purpose of the sampling section. The sampling section holds the amplitude and filtered waveform in short term memory while voltage readings are taken. The voltage readings are taken to convert the time domain into a table numbers.

3.1.2.3 Windowing

There is another property of FFT analyzers that the operators must be aware of. This is windowing. We know that digital sampling takes place during discrete blocks of time. The FFT analyzer assumes that signal present in that block of time is present for all time before and after the sampling. This block processing is necessary in real world data acquisition. We cannot wait for infinity to see if the signal is periodic to infinity. The Fourier Transformation, however, makes this assumption and it can produce error called leakage, if the signal does not match up at the beginning and end of a time block. This leakage is undesirable, but we can reduce this leakage using window function. There are three useful window functions:

[1] Henning window: for typical measurements during machine monitoring.
[2] Uniform window: for maximum frequency.
[3] Flattop window: for maximum amplitude accuracy.

3.1.3 Features of FFT Analyzer Spectrum

Now, we discuss some useful features of FFT analyzer spectrum.

3.1.3.1 Averaging:

One very useful feature of these instruments is averaging. Averaging has the ability to combine time records with previous data to smooth out the display. This is very useful because vibration data is not usually stable, i.e. it is always changing. Averaging allows you to smooth out the spectrum with data over a long period of time. The summation averaging mode is the one normally used for machine monitoring. For periodic monitoring, as in predictive maintenance program, it is strongly recommended to do summation averaging.

3.1.3.2 ZOOM

Zooming is the ability to expand a portion of the spectrum, which is useful in separating out closely out spaced frequency components. Zooming is also useful as a tachometer to measure speed accurately.

4. VIBRATION MONITORING PROGRAM

The biggest saving to be gained from a vibration monitoring program is avoiding losses due to unexpected breakdowns. Use this as a criterion for deciding if a monitoring program is for your operation. Critically examine every piece of equipment in your operation and ask yourself, “if this machine break now, what would be consequences be? If consequences are not serious, it may be better to let it run until it breaks. Some equipment is large and expensive and unreasonable to back up. An example is a chiller that provides process chilled water. This kind of equipment, unduplicated and critical, is a good candidate for health monitoring. A vibration monitoring program costs money. There is an initial investment in instruments. But this investment is small as compared to manpower required to collect data analyze it. If you decide to conduct vibration monitoring program, there are some steps to get successful program.

4.1 Get management commitment for a long term program

Management must commit financially for the instrument investment, training and time for data collection. This is a long term improvement program. Obtain management commitment to allow it to run for at least a year.

4.2 Select and train personnel :

Identify one or two people who will have responsibility for this entire program. Ideally, this would be an engineer and a technician. Give them ownership of everything. Send them for training and seminars. Allow them to select instruments to use. Allow them the machinery to monitor and to design the data collection system. Do not attempt any level of vibration monitoring program without engineering support. Engineering support required to:

- Interface instruments
- Program the system
- Co-ordinate with equipment manufacturers
- Analysis

4.3 Select machines to monitor

Select with less number of machines to monitor. Pick the most critical machines. Identify problems in the machines and give all information to management.

4.4 Take baseline data

While your instruments are on order, mark the machines you want to monitor and set up a route. Some machines may be in hazardous locations or otherwise unsafe to get to. The next step is to collect baseline data for all machines you initially want to monitor. You should take at all bearings. Even though you may only monitor one point on a machine, you should collect and store baseline data at all bearings. Compare this baseline data against industry standards to see how the equipment compares. You can also compare similar machines in your plants. Do some analysis to see what is out of balance, is misaligned, has bad bearings, etc.

4.5 Start your monitoring program

A good starting interval is monthly. You can extend this to 2, 3 or 6 months later if things look good. The purpose of this monitoring is to trend the data and look for increases. A sketch of the machine is useful to show measurement point. It is good idea to take vibration reading before and after major maintenance. This is a good quality control of the work done.

4.6 Prepare monthly report

Management, who invested in this program, like to know if it is doing well. Don’t keep them in dark. If everything is running smoothly, let them know and feel good about it too. This visibility to management is what gives your program credibility. In time, you will find management clamoring for vibration reports at the slightest hint of anything going wrong.

4.7 Results of monitoring program

- If you will perform good monitoring, in time, the monitoring program will take the form of a pyramid as shown in figure below.
- At the top of the pyramid are a few machines with serious defects that require close scrutiny.
- Next are those that require detailed diagnostics because of an upward trend or other irregularity.
- Below that are the machines that are routinely trended.
- At the bottom are the large numbers of good machines that may or may not have vibration data on record but are not mentioned on a regular basis.

5. SAFETY PRECAUTIONS

While taking vibration measurements, you will be working around rotating equipments. You should take some safety precautions while taking measurements. A few safety precautions are in order:

- Beware of bumping hazards. Move slowly, but deliberately, around mechanical equipment to avoid bumping hazards to your head. Wear a hard hat and ear plugs where appropriate.

- Tuck in all loose clothing and roll up your sleeves so that it cannot entangle in rotating equipments. Be especially careful when covers are removed from couplings or belts.
- Stay out of machine's "line of fire" as much as possible.
- Watch your steps. Sometimes, when taking vibration measurements, cables are on the floor or spanning open spaces between transducer, instruments and power sources. Do not step on those cables. Be aware of stroboscopic illusions. Be always alert when machinery is rotating. Avoid the temptation to touch it when freezing its motion with a strobe. Turn off the stroboscope when not in use.
- Be aware of high voltages. You will be working around high voltage and many times, high current wiring. Be observant and avoid high voltage hazards such as improper grounding, damaged wire, etc.
- Have someone familiar with the system shut down equipment. This ensures that the correct switch is thrown and proper coordination is done with user.

6. CONCLUSION

Vibration is one of the important parameter in mechanical system which directly affects on the efficiency of a machine. Thus, it must be necessary to reduce the vibration by arranging vibration monitoring program at specific interval, so that we can increase life of machinery i.e. indirectly we can increase profit of a company.

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