

Vibration Analysis: A Literature Review

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Abstract: This paper covers the basic idea behind the vibration analysis and uses that information to reduce failures and thus save resources. This paper gives an idea on why vibration monitoring is important, How vibration is described? and, How to measure these vibration?.The extend of vibration analysis depends on the purpose of carrying out vibration analysis.

Keywords: vibration , monitoring , analysis.

I. Introduction

We all are familiar with vibration in one or the other form . The different form of vibration can be sensed by seeing, touching etc here we are concerned about the vibration of machine or its parts. The perception of human beings vary from person to person, if one person finds that particular vibrations are bad for the proper working of machine , any other person may find it useful .Some vibration are beyond the range of human perceptions [3].Thus many new technologies came into existence to measure and analyze the same. So , what is vibration ? It is the to and fro movement of machine or its components. These vibration may sometimes be designed for some purpose or in some other cases damages the machine. The vibrations cause loss in money and time [2]. Here mainly we are dealing with unintended machine vibrations. Vibration is inversely related to the lifetime of the machine. Low levels of vibration indicate low vibratory forces , resulting improved machine life.

When the machines performance deteriorates , the dynamic forces generated by the machine will increase intensity , causing an increase in machine vibration or the physical integrity of the machine will be reduced , causing an increase in the machine vibration. There are mainly four factors that determine the characteristics of vibration and they are : the exciting force(which is due to the misalignment or looseness), mass of the vibrating system , stiffness of the vibrating system and damping characteristics of the vibrating system. The last three factors tries to stop or minimize the vibration whereas the first factor causes the vibration.

II. Cause Of Vibration

There are mainly three factors that causes vibration:

A. Repeating forces

A force of a pattern repeated over and over again [1]. These repeated force acting on a machine again and again leads to machine vibration .This repeated forces are due to the improper, worn or misaligned machine components. Among them around 40 percent is due to imbalance , 30 percent is due to misalignment , 20 percent is due to resonance and 10 percent is due to others issues. Imbalance is caused by the machining errors, non-uniform material density etc. Whereas the misaligned components leads to bending moments which creates repeated forces. This misalignment is due to inaccurate assembly , thermal expansion etc.

B. Looseness

Loose machine parts can cause vibration . When some parts become loose it may cause severe vibration. Looseness causes vibration in both the rotating and non-rotating machinery. The looseness is mainly due to the loose bolts, uneven components etc.

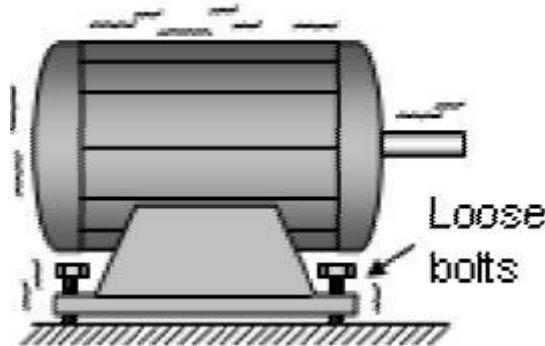


Fig.1 looseness

C. Resonance

Every machine has its own one or more natural oscillation rate, so when an external force is added to the natural oscillation of a machine, which makes more vibrations. This external oscillations added to the natural oscillation is called the resonance. As the complexity of the machine increases so do the natural oscillations. The resonance should be avoided because it may cause severe damage. An example to give is bridges have collapsed when their natural oscillation rate is being excited by the mere marching of the soldiers in unison across the bridge.[1]

III. Need For Monitoring

- i. Monitoring the machine gives us the idea about the health of the machine we are dealing, which in turn helps us to improve the ability, life time of the machine.
- ii. The worst case is that wait until the machine breaks, which leads to loss in time and money.
- iii. Undetected vibration causes severe machine damage or replacement of the whole machine.
- iv. Machines which vibrate consumes more power than usual.
- v. Unmonitored machines may break down, if the replacement is not readily available, it leads to delay. In other words it is still a loss.
- vi. Regular monitoring helps to identify the new error and rectify it as early as possible.

IV. How Vibration Is Described ?

As said earlier by mere feeling, watching and listening the severity of some vibrations can be determined i.e., sometimes hot or noisy machines shows that some things are wrong about it.

Rather than expressing vibrations verbally, numerical descriptions are better. The two major numerical descriptors are amplitude, frequency. Amplitude describes the severity of the vibration, so machines with higher magnitudes are more prone to vibrations. The overall vibration measurements are usually expressed in terms of rms [4]. Root mean square or rms amplitude is an indication of the energy of vibration. The vibration energy is directly related to the root mean square amplitude. The rms should always be lower than peak amplitude. The above feature is good to track the overall noise level but it does not give the idea on which component is failing. It gives good idea about the imbalance of the rotating system [6]. The rate with which the machine component oscillates is called the vibration frequency or the oscillation. Frequency describes the oscillation rate of vibration [1]. Higher the vibration frequency indicates the faster oscillations made by the machine. The units used to express the frequency is cycles per second(cps), cycles per minute (cpm) and Hertz(Hz).

$$1 \text{ Hz} = 1 \text{ cps} = 60 \text{ cpm}$$

A waveform is a graphical representation of how the vibration level changes with time [1]. The information contained in the waveform depends on the duration and resolution of the waveform. The total time period over which the information is obtained from the wave form is called the duration. The level of detail is defined as resolution or the number of samples present in the waveform.

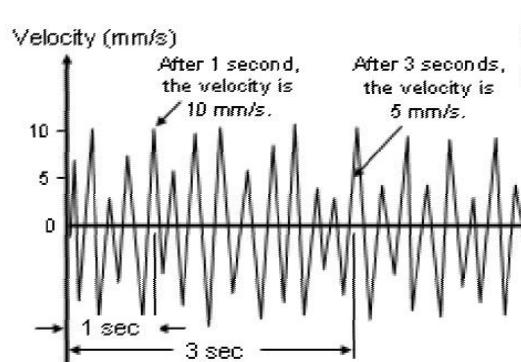


Fig. 2 waveform

Similar to waveform a spectrum is also used in vibration analysis. Spectrum is a graphical display of the frequencies at which a machine component vibrating[1]. It is very useful analytical tool. The spectrum is mostly used in vibration analysis. The information a spectrum contains depends on the Fmax (maximum frequency) and the resolution of the spectrum. The Fmax depends on the operating speed of machine. Resolution depends on the spectral lines and more spectral lines means more detailed spectrum.

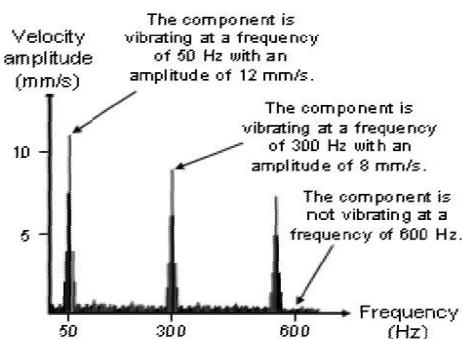


Fig.3 spectrum

V. How Vibration Is Measured?

A. Machines that need to be monitored

- Those machines that needs costly, lengthy or difficult repairs if broken down are given more priority in the list.
- Those which plays important role in the required system.
- Those which suffer frequent damages in the past.
- Those machines which may cause threat to people and environment on damage.

B. How does the instrument work?

A sensor should be attached to the machine whose vibration is to be measured. Accelerometer is used as sensor which produces electrical signals based on the acceleration of the vibrating component[1],[6]. This captured signal is converted into velocity signal, can be viewed as the users choice i.e., waveform or spectrum.

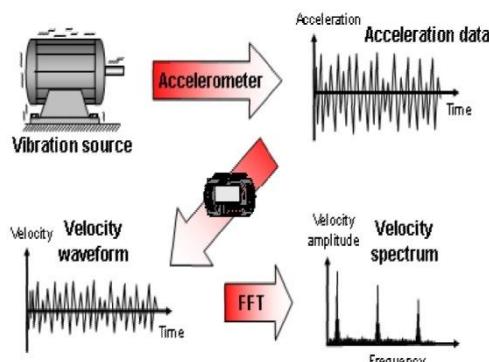


Fig.4 working of instrument

The signal can be converted to velocity spectrum by applying Fast Fourier Transform on the velocity waveform which is depicted in the above figure.

C. Mounting of the Accelerometer

Most of the pumps and motors will have a rotary mechanism , which in turn have bearings that helps in rotation of the machine that causes vibration. Thus the measurements of vibration is done at the same location i.e., at the bearings. Mounting of the accelerometer determines the accuracy of the measurement. The vibration frequencies measured by the accelerometer can change rapidly in time, especially if a fault has occurred [5].

These are the following things that should be taken care while mounting the accelerometer:

- i. Accelerometer should be mounted as close to the bearing.
- ii. Also make sure that it is attached firmly to the vibrating part of the machine. There are several available methods for mounting the same , among them the most commonly employed is magnetic method. This method provides maximum balance to the accelerometer attached. And before mounting the magnet to the surface of the component , the surface should be free from rust , the surface must have a magnetic property .
- iii. The orientation of the accelerometer is another important factor , it should be oriented either horizontally or vertically with the measuring component.
- iv. Make sure that the accelerometer is mounted at the same location to maintain consistency in measurements.

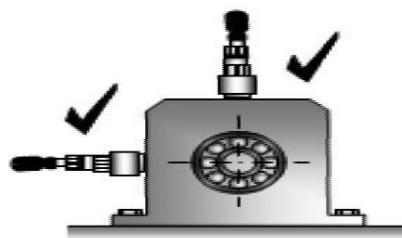


Fig.5 proper mounting of accelerometer

- v. It should not be mounted on any flexible surface or any external structure which is of light weight that can distort the vibration of the structure.
- vi . Accelerometer should be treated with extreme care , the cable of the accelerometer should never be twisted which leads to distortion in vibration signals.
- vii. Personal safety should be ensured while mounting the accelerometer.

D. Measuring parameters

Prior to vibration the parameters that are needed in vibration should be determined . This parameters include how data is collected, how fast the data is collected, how it is processed and how it is displayed. In the first case the sensor type is determined, single or multiple readings should be taken all these factors are be taken into consideration. Whereas , in the second parameter it determines the range of Fmax(maximum frequency), spectral line and the overlap percentage. As mentioned earlier the when Fmax increases , the vibration also increases and same is the case with spectral lines, as the number of spectral lines increases the information obtained from the spectrum is more. Overlap means the amount of information taken from the previous measurement to obtain the new measurement. So only less amount of current data is required to generate spectrum which makes the data collection faster.

In the third case the is processed by taking the average of the spectrums taken earlier. The average is taken because it represents the true behaviour of the vibration signal.

In the last case it describes how data is collected, visiting the site every now and then to take the account of the vibration data is waste of time so the readings taken should be stored in some memory and are then processed.

VI. Methods Used For Vibration Analysis

Fourier series analysis is good when the signal used is stationary, it is not good when a non stationary signal need to be analyzed. If a signal is converted to its frequency domain the time domain information is lost. That is when looking at a Fourier transform of a signal , it is impossible to say when a particular event took place[7],[8].

In order to overcome this deficiency another method called windowing is being introduced i.e, a small section of a signal is selected at a time. Short Time Fourier Transform (STFT) ; it maps the signal into a two dimensional function of time and frequency. But here the information is limited because the rate of information obtained is related to the size of the window used. So the main drawback is that once the size of the window is set it will be same for all frequencies.

Thus to overcome these deficiencies wavelet toolbox is used i.e, it supports variable sized regions. Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques fail. A wavelet is a waveform of effectively limited duration that has an average value of zero [7]. Wavelets are irregular and asymmetric. In wavelet analysis the signal is broke into shifted and scaled version of the original wavelet [7],[8].

VII. Conclusion

In this paper I have emphasized the importance of collecting and analysis of vibration data . Scheduled analysis of vibration data helps to maintain the health and thus improve the life time of the machine which saves the time and money . A wavelet toolbox is found to be a good tool for the better analysis of the non-stationary signals when comparing with FFT.

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