High Frequency Analysis with Advanced Technologies

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Presentation for:
Vibration Institute - Piedmont Chapter #14
May 2008

High Frequency Waves

Why they are different.

Definition

- High frequency wave action is generally considered to the condition reached when the dimensions of the wave and the objects it encounters have similar dimensions.

Different but the same

- The condition can be reached in virtually all physical wave applications. Electronic, light, sound, pressure. even traffic and helicopters can exhibit strange wave behavior.

Standing Waves

- The condition arises when the transmission medium has discontinuities and the overall dimensions are such that waves upon reaching the discontinuity are reflected back and forth. If the transmission losses are low, the moving energy will create standing waves

The Good and the Bad

- These standing waves can be extremely useful or very damaging depending on the situation. A laser or a piano string is a situation which uses the properties of standing waves for good. A machine structural resonance is an example of a standing wave that is often very destructive.

How to make them

- So when is a standing wave likely to be created. First there must be a discontinuity in the transmission medium. An empty room is a good example of discontinuities. The room is full of air as a sound transmission medium and the rigid flat walls create a near ideal discontinuity.

The Set up

- Second there must be a source of sound energy at a constant frequency. If a speaker is positioned at one end of the room and supplied with a source of sinusoidal energy it will launch a sound wave (longitudinally) toward the other end of the room. Assume for the moment the only discontinuity of interest is the one at the far end of the room.

Quick Math

- In air sound travels about 1100 feet per second and sea level. We can calculate the wavelength of any given frequency by using the equation wavelength = 1100 / f in Hz. For example, if the room is 10 feet long and the frequency is 20 Hertz the wavelength is about 1100 fps /20 Hz or 55 feet. If the waveform is very long compared to the room length the pressure at any point in the room will pretty much uniformly rise and lower.

How to make them, Cont’d

- A person standing anywhere in the room will hear the constant tone.
- If the frequency is raised to 1100 Hz. The wavelength will now be about 1 foot. The situation will be similar when the individual is near the speaker, however as the listener moves toward the far end of the room the conditions will change.

Making them, Cont’d

- When one of his ears is about 6 inches from the wall he will not be able to hear the tone. This is because the incoming tone from the speaker and the reflection from the wall (the discontinuity) are very nearly the same amplitude and are exactly 180 degrees out of phase.

Making them, Cont’d

- The reflection cancels the incoming direct sound and the ear has nothing to hear. Notice this condition will occur only is the tone is constant in frequency. It is however not necessary for the tone to be any specific frequency. The frequency must only be high enough for multiple reflected (Standing) waves to be created with in the room.

Why Care?

- The exact position of the null will move about but it will always exist if the discontinuity is highly reflective and the dimensions are suitable. When the dimensions The point of the above laborious discussion is this.
- If the wave energy being evaluated and the dimensions of the object transmitting the wave energy become similar the possibility of developing null points in the transmission path is very likely.

- When we make high frequency vibration or sound measurements, (As in Peakvue) we have a very good possibility of missing information if the care is not taken to scan the unit surface for energy peaks.

High Frequency Test

- Demonstration of acoustic standing waves. (500 - 1000 Hertz)
- Plug one ear with a finger
- Move near to a clear flat wall. (2 to 4 foot range). Move unplugged ear about until you notice even though the sound level is not being changed as it is being generated you can still find high and low levels of the sound.

Low Frequency Test

- Repeat with 50 Hertz sound.

Standing waves are no longer created. The room is to small.

PeakVue

Why It works

Stress waves

- Assuming it is not destroyed by some form of misuse, A rolling element bearing will eventually die of old age.
- The mechanism is fatigue. The rolling element itself is distorted slightly as it passes in and out of the load zone. The races are also distorted slightly by the rolling element.

Bearings

- All most all metals have a similar fatigue failure curve. Cyclic stress is plotted vertically and number of cycles to failure is plotted on the horizontally. Most metals do not ever reach a stable condition such that eventual failure is not guaranteed. This true no matter how much the cyclic stress is reduced.

Bearings

- The cyclic stress eventually causes a failure of the metal. This failure will occur around some microscopic defect in the metals crystalline structure. The actual failure may occur on the surface of the metal (Visible) or it may below the surface (Invisible) The crack will grow and eventually a piece of the bearing element will separate form its parent metal (A spall).

Bearing Stress Waves

- When the defect first occurs the microscopic rubbing of the surfaces will create high frequency vibrations known as stress waves. The effect is similar to the noise produced when a very cold ice cube is dropped into a warm drink. The ice makes noises generated by the thermal stress.

Stress waves Cont’d

- These waves although very weak have the advantage of being very high in frequency.

This means the inherent machine vibration ---- 1X, 2X, looseness, vane pass, etc. is well below the stress wave frequencies. It is therefore possible to utilize a high pass filter to remove all of the inherent vibration allowing the entire dynamic range of the analyzer to used to process the stress waves.

Peakvue Processing

- The stress waves are created by the bearing elements and therefore they have the same bearing element repetition rate as the directly created bearing fault frequencies. They are however not coherent with each other which means special processing is required to extract useful results.

PeakVue Processing

- Two separate operations are performed.
- Since the duration is very short the analyzer is programmed to sample as fast a possible, ensuring there as many individual wave peaks are captured as is possible. All of these values are then sorted to find the biggest peak present in each desired time block

PeakVue Processing

- Since they are not coherent there is no advantage to maintaining the positive and negative peaks as such. The second step is to full wave rectify the chosen peaks to make them unipolar. The final step is to store the values an though they were waveform samples and perform the FFT as normal. Since the stress waves are created by the bearing element fault energy the they will possess the timing of their origion and fault frequencies will be present.

Caveats

- Peak Vue processing can identify defects that while real are below the bearing surface and cannot be seen by any form of microscopic inspection. It is probably best to use Peak Vue as an early warning tool and wait until normal bearing frequencies appear before scheduling a maintenance action.

VFD’s Good or Bad

Where do the troubles start?

What is a VFD?

- A VFD is an AC to DC to AC converter
- Step 1-----3 phase AC is rectified to make it uni directional, filtered, and turned into the equivalent of battery (DC) power. This step is common in many, many house hold and industrial products. There are a few problems that are created in the form of distorted current waveforms. Such distortion is of little consequence and can be minimized with a slightly more expensive power supply design.

Converting back

- The DC power (plus volts and minus volts) must now be changed back to 3 phase AC voltages at the frequency desired. Ideally, the new AC would be as good a sine wave as that created by turbo generators. This can be done. The concept is no different to that used in stereo power amplifiers. The difficulty is the conversion process will not be efficient. (About 50 percent of the energy will be lost as heat.)

Enter Switching Concepts

- If instead of linearly reshaping the DC into the AC sin wave, It is possible to use switching devices to create an wave pattern having the energy proportions and timing of a sin wave but actually having only two voltage levels (on and off). This process is much more energy efficient. In theory, 100 percent.

Switched waveforms

- The problem is the switching must be very fast compared to the frequency of the power desired (30 – 90 Hertz). Typical switching frequencies range from 2 Khz to 40 Khz. The bulk of the energy is shaped to a sine wave that the motor can use to create the necessary rotating magnetic field needed to produce useful power.

High Frequency energy

- The problems begin with the remainder of the energy which the motor subjected to. This energy has very high frequency spectral lines. High frequency components see capacitance as a short cut back home.
- A 60 Hz AC motor is designed to see only 60 Hz energy plus maybe a small amount of harmonic distortion.

Frequency and Capacitance

- Volt for Volt, a 6 Khz signal will produce 100 times of the capacitive current a 60 Hz signal will produce (Same capacitor).
- The motor was not designed to accommodate such currents. In general, the currents are intent upon getting the ground. The best path to ground may well be through the bearings, hence fluting problems.

Insulation Problems

- Not all insulation systems can effectively accommodate high frequency energy. The insulation itself may absorb the energy creating local heating.
- The iron laminations will likely have higher losses at the higher frequencies resulting in more local heating.

Other Problems

- Speeding or slowing a motor can create cooling problems.
- A motor running at a higher speed usually has to produce more horsepower to carry the load.
- Physical noise may be a problem for nearby humans or other sensitive processes.

Cures

- VFD switching energy can be filtered out.
- It only takes a large low pass filter on each phase. Large inductors and capacitors are expensive.
- These filters must be designed for the task or they will themselves fail for many of the same reasons the motors do.

Cures Cont'd

- Ceramic Bearings will eliminate electrical damage
- Use of external forced cooling air will help remove excess heat and prevents a reduction of airflow when the motor is run slower than normal.
- Remember a 10 HP 3600 RPM motor can only yield 5 HP at 1800 RPM. (Usually not even that much)

Cures Cont’d

- Precision balancing and alignment goes hand in hand with any speed increases.
- A VFD is the finest way ever created to locate machine resonances.

Avoiding Trouble

- Do not use a VFD with an old motor.
- Buy a new motor designed for VFD use.
- Preferably buy the VFD and the motor from the same supplier.
- Are VFD’s going to go away. No!!!
- They will be around for a long time and the pain will subside as experience spreads.