BEARING DIAGNOSIS

Enveloping is one of the most utilized methods to diagnose bearings. This technique is based on the constructive characteristics of the bearings and is able to find shocks and friction even from the very beginning of a flaw.

Bearing casing vibrations

The bearing case can vibrate for multiple reasons: imbalances, misalignments, shocks, etc. Unlike the other vibration sources, following the high speed forces variation, the shocks may excite the bearing case at its resonance frequency.

Of interest in the bearing diagnosis are the occurrence frequency and amplitude of such oscillations.

Although the resonance frequency manifests within a rather narrow frequency band, the amplitude modulation process resulted from those shocks and the variation of the transmission conditions, calls for an analysis over a broader frequency band centered on the resonance frequency.

The increasing of the analysis band is often limited by the presence of the high frequency signals that overlap that band.

Fault frequencies

The occurrence frequencies of the shocks resulted from the faults in the bearings are called fault frequencies. They depend on speed and bearing geometry. Knowing the speed, we can get a direct relation between the measured fault frequency and the type of flaw.

Fault frequencies are being computed by the following formulas:

FTF - Fundamental Train Frequency (fault on the cage or mechanical looseness):

$$\text{FTF} = f_r \frac{1}{2}\left(1 - \frac{BD}{PD}\cos\beta\right)$$

BPFO - Ball Passing Frequency Outer Race (local fault on outer race):

$$\text{BPFO} = f_r \frac{n}{2}\left(1 - \frac{BD}{PD}\cos\beta\right)$$

BPFI - Ball Passing Frequency Inner Race (local fault on inner race):

BPFI = $f_r \frac{n}{2}\left(1+\frac{BD}{PD}\cos\beta\right)$

BSF - Ball Spin Frequency

BSF = $f_r \frac{PD}{2BD}\left[1-\left(\frac{BD}{PD}\cos\beta\right)^2\right]$

BFF - Ball Fault Frequency (local fault on rolling element):

BFF = $f_r \frac{PD}{BD}\left[1-\left(\frac{BD}{PD}\cos\beta\right)^2\right]$ =2 * BSF

Where

n - number of balls or rollers
f_r - relative revolution between inner and outer races
β - contact angle
BD - ball diameter
PD - pitch diameter

Enveloping

The vibrations signal envelope is a low frequency signal that follows the peaks of the filtered input signal.

The envelope frequency spectrum contains components with a frequency equal to the impact occurrence rate and amplitude proportional to their energy.

The main steps in the vibrations envelope analysis are:

- Filtering
- Enveloping
- Decimation
- Spectrum analysis

Bearings analysis with DSA 500

The 100 kS/s/ch acquisition speed, 24-bit resolution, and the 524288-sample analysis buffer make the DSA 500 analyzer be fit for high accuracy diagnosis.

The *Bearing Diagnosis* function monitors a range of waveform and frequency spectrum parameters that are specific to bearing diagnosis.

Fault frequencies are computed from the input data on the bearing geometry, or loaded from a user-customized database.

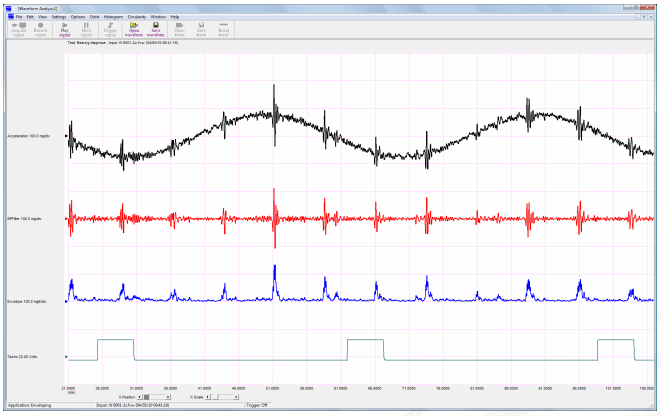
Cursors to identify the fault frequencies, their harmonics and combined faults are available.

The vibrations signal may be simultaneously process on multiple channels in order to monitor both the overall machine status (overall vibrations, imbalance faults and misalignments) and the status of one or more bearings.

The analysis may be performed in the frequency range for the constant speed regimes or order range for the transient regimes.

Besides the specific bearing fault noise, the vibrations signal contains certain signals of various sources: imbalance, misalignment, gearing, and high frequency noises.

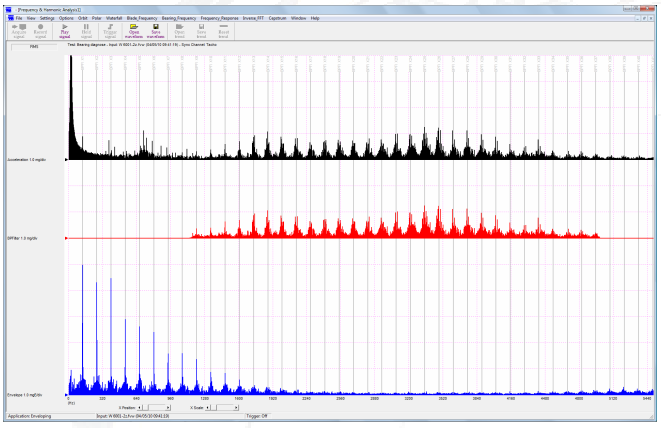
Band-pass FIR filters remove these components while keeping the position and amplitude of the bearing's faulty components unaltered.



Waveforms of input vibrations, filtered vibrations, vibration envelope and tacho signal

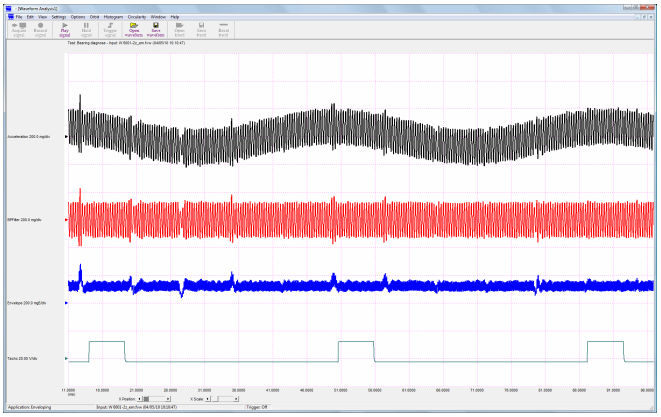
The spectrum analysis of the input signal and filtered signal leads to the overall assessment of the machine and bearing status, and the optimization of the filter.

The envelope frequency spectrum shows the fault type and gravity.



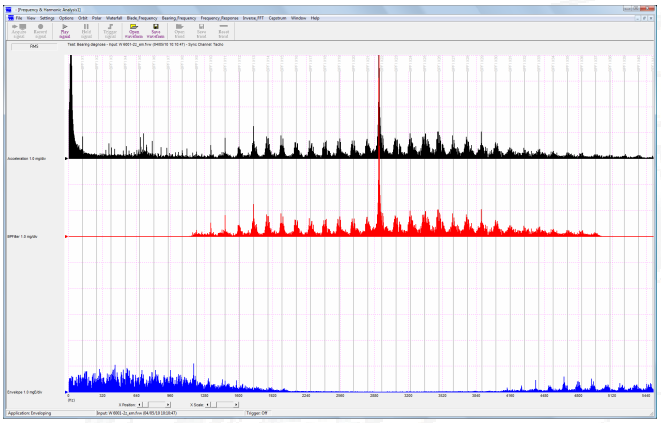
Frequency spectrum of input vibrations, filtered vibrations and vibration envelope

The enveloping operation is sufficient provided that the bearing fault signal is being as centered as possible on the zero value. The presence of a perturbation in the resonance band may vertically translates the fault signal so that it could not pass through zero anymore.



Waveforms when the resonance band also contains vibrations caused by the motor's electromagnetic forces

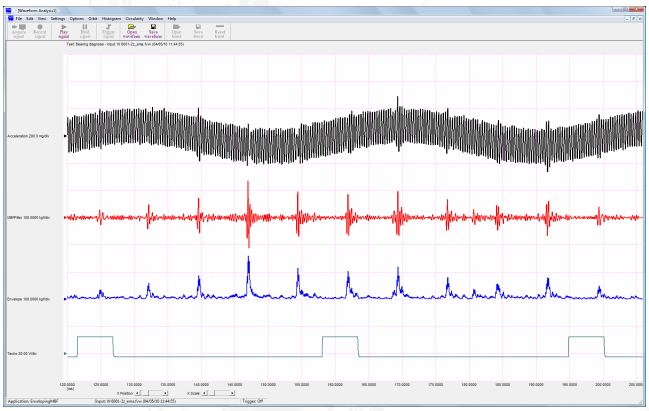
The presence of a perturbation in the resonance band makes the envelope's frequency spectrum not contain the components specific to the bearing fault.



Frequency spectrum when the resonance band also contains vibrations caused by the motor's electromagnetic forces

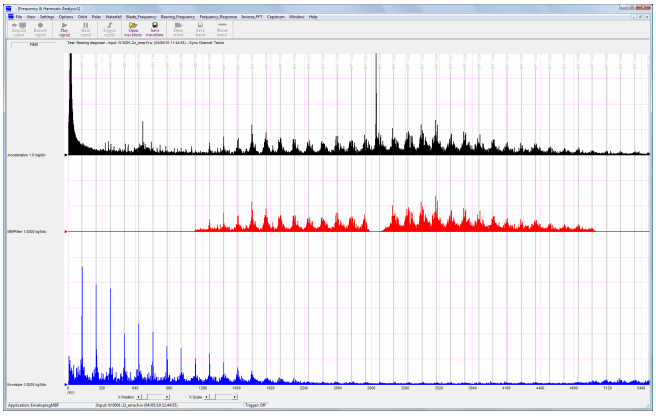
Multiple band-pass filtering allows maintaining a broad analysis band by selecting those bands that are not affected by unwanted signals.

The signal obtained is available for both the envelope and the waveform analysis.



Waveforms after multiple band-pass filtering

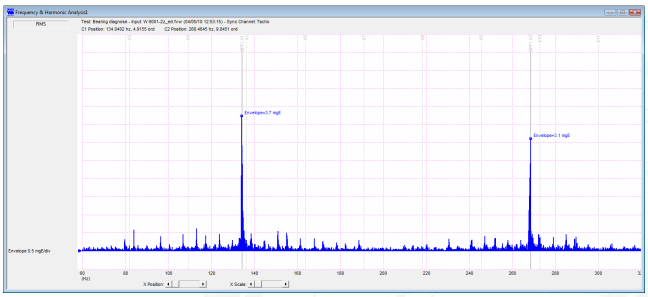
Keeping the bearing fault energy by using the multiple band-pass filter helps identifying it in the envelope spectrum even from the beginning.



Frequency spectrum after multiple band-pass filtering

Frequency resolution is an important factor in the identification of the bearing faults and accurate determination of the bearing's functional and constructive characteristics.

Through the decimation operation and spectrum analysis over 262,144 lines, DSA 500 provides a milihertz resolution while the frequency domain is tens of kilohertz.



Increasing the spectrum analysis resolution through the decimation operation

The parameters of the input, filtered and envelope signals are recorded in a proprietary, Excel or Access format for monitoring and trending the overall condition of the machines over time.

Non-linear trends generally are an indication of impending problems. This warning enables the maintenance department to schedule the necessary repairs before an unexpected failure occurs, causing downtime and lost productivity.

Machine status network monitoring

DSA 401 helps monitoring multiple machines over a wireless or cable network. High-speed data are being sent to the analysis system for complete and high-accuracy diagnosis.

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