Derived POINT Application: Harmonic Activity Locator (HAL)

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Requirements

This article assumes the reader has sufficient knowledge of the following concepts: Harmonic Series, and Setting up Derived POINTs. Harmonic Activity Locator technology is available for the SKF @ptitude Analyst CMSW 7400 software platform only.

Abstract

Harmonic Activity Locator (HAL) is a post process operation that operates on FFT spectra. The output of the HAL process is a Harmonic Activity Index (HAI) that aims to express the likelihood of a fault pattern being present. HAL operates on the idea that impulsive forces create impact signals consisting of a fundamental frequency and many harmonics. Rather than attempting to qualify each individual harmonic by means of, for example, a band alarm, HAL evaluates the entire harmonic pattern and assigns it a dimensionless likelihood index.

HAL is supported by several different spectral cursors including the Frequency Analysis cursor, Harmonic cursor, and the special Diagnostic cursor. With HAL support for derived POINTs, HAI values can be trended and alarmed upon.

This article provides a brief description of HAL and an explanation of its function through derived POINTs.

Impact signals and harmonic series

The term "impact signal" implies a vibration signal that is formed by one or more abrupt changes. An example would be a signal caused by a hammer striking an object. If measured by an accelerometer, the signal would show a large pulse in the time waveform. In a bearing, a rolling element rolling over a fault in the raceway has a smallbut measurable abrupt change in its path, and therefore creates an impact signal. Fourier teaches us that complex signals are composed of a series of sinusoids with different frequencies, amplitudes, and phase angles. A fault signal therefore can be shown to have a spectral content consisting of its fundamental frequency and higher harmonics that all have an exact integer relationship to the fundamental frequency.

On their way from source to sensor, signals often undergo some change. Some spectral content may be attenuated or suppressed due to mechanical construction and dynamics of the system as a whole, including sensor characteristics. Therefore, the actual system response is highly dependent on the application along with the dynamics of the system. This implies that some harmonics of an impact signal may be affected - but not all. Also, if characteristics of the machinery under observation change, this may cause other harmonic frequencies to become affected. Therefore, an absolute level set against each individual harmonic is often a difficult task, and not without errors. It is important to recognize the entire harmonic pattern as a whole and assign it some index which assesses its importance or likelihood.

The HAL process

HAL operates on spectra, determining the precise amplitude value of a fundamental frequency and its harmonics. It does so even if harmonic frequencies do not fall exactly on spectral bins. In such cases, HAL uses an interpolation technique that estimates the harmonic content "in between spectral lines."

HAL assigns a harmonic pattern a Harmonic Activity Index (HAI). It does this by computing the ratio of:

- all harmonic content, and
- all non-harmonic content

The ratio tracks how much a harmonic pattern "stands out" of the noise or other signals present in the spectrum under study. Index values of 2.5 and higher typically indicate a very visible harmonic pattern (i.e., the point whereby a human observer would typically say that "there is something there"). With higher index values, the pattern that emerges becomes increasingly clear (i.e., an HAI of 5 usually leaves no room for guessing).

Optimizing measurements for HAL

Naturally, measurements that contain only a few harmonics have a lesser degree of accuracy. One can change the number of harmonics captured by changing the Fmax value (i.e., the maximum frequency value with which the spectrum is captured). The higher the Fmax, the more harmonics are captured. However, this also means that the waveform is captured in less time, which in turn means that less resolution is available for studies in the time domain. Also, capturing measurements with endlessly more harmonics does not lead to continually increased accuracy with the HAL function. One can imagine that small inaccuracies in the machine speed reading will lead to very big accuracy problems with the high harmonics. In addition, there are limitations to the data collector's capabilities to capture more and more data (time domain waveform length).

Therefore, generally speaking, it appears that measurements capturing between 10 to 20 harmonics are ideal for HAL. This coincides with what most human operators regard as a practical range. This does not mean that HAL's values are not usable outside this range. The example in **Figure 1** was indeed proven to be an outer race bearing fault, which the HAL trend captured more than a month before the overall value trend alarmed.

To which measurements can HAL be applied?

HAL measurements can be applied to any spectrum, without limitation. Naturally, acceleration, velocity, and acceleration enveloping measurements "behave" differently. This remains true even with HAL applied to these spectra. HAL will provide the likelihood that these measurements show a harmonic pattern, and does this regardless of the measurement's unit. Therefore, it remains important to follow a multi-parameter approach to measuring faults.

Where is HAL implemented?

For SKF @ptitude Analyst, HAL functions are implemented for:

- Bearing frequency module; each cursor has an HAI attached
- Harmonic cursor; while moving the cursor, the HAI is updated continually
- Diagnostic cursor; evaluates the entire spectrum and presents a list of likely patterns
- Derived POINTs; allows HAI to be trended through an embedded function.

The HAL() derived POINT function

SKF @ptitude Analyst specifies the HAL function as:

HAL(<DYNAMIC VARIABLE> ,<SPEED MULTIPLE>)

Whereby <DYNAMIC VARIABLE> is the FFT variable and <SPEED MULTIPLE> is the order of the defect under study. Spectra with a zero speed will result in a zero HAI.

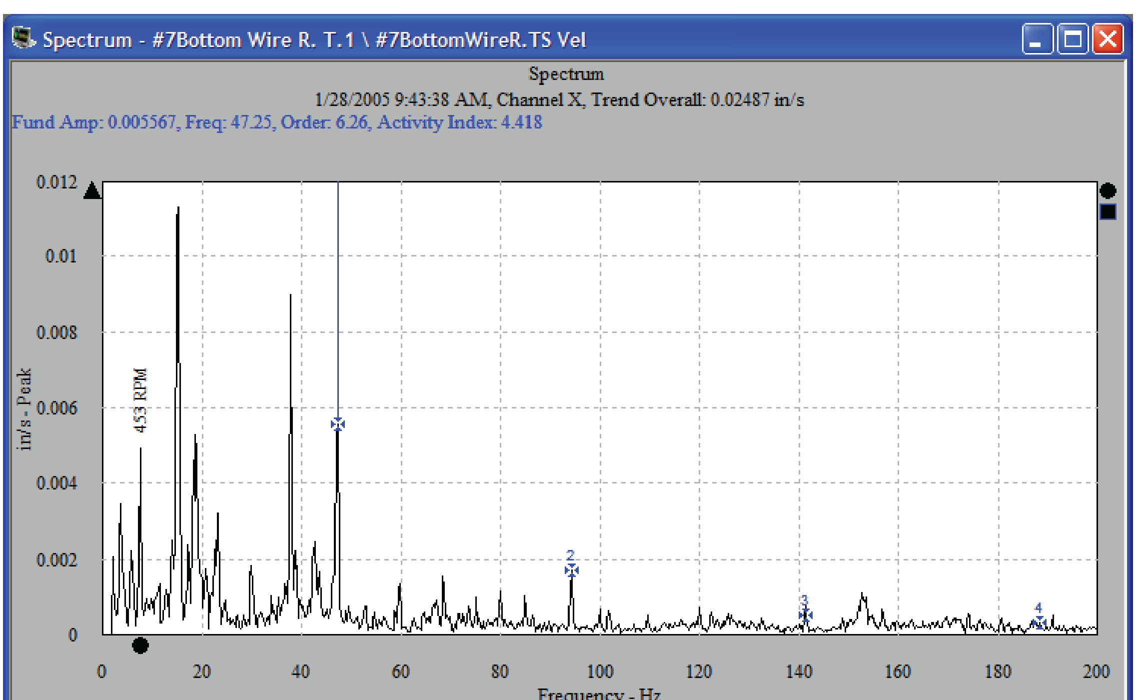


Figure 1. SKF @ptitude Analyst showing a spectrum with a harmonic cursor indicating BPFO (HAI = 4.418).

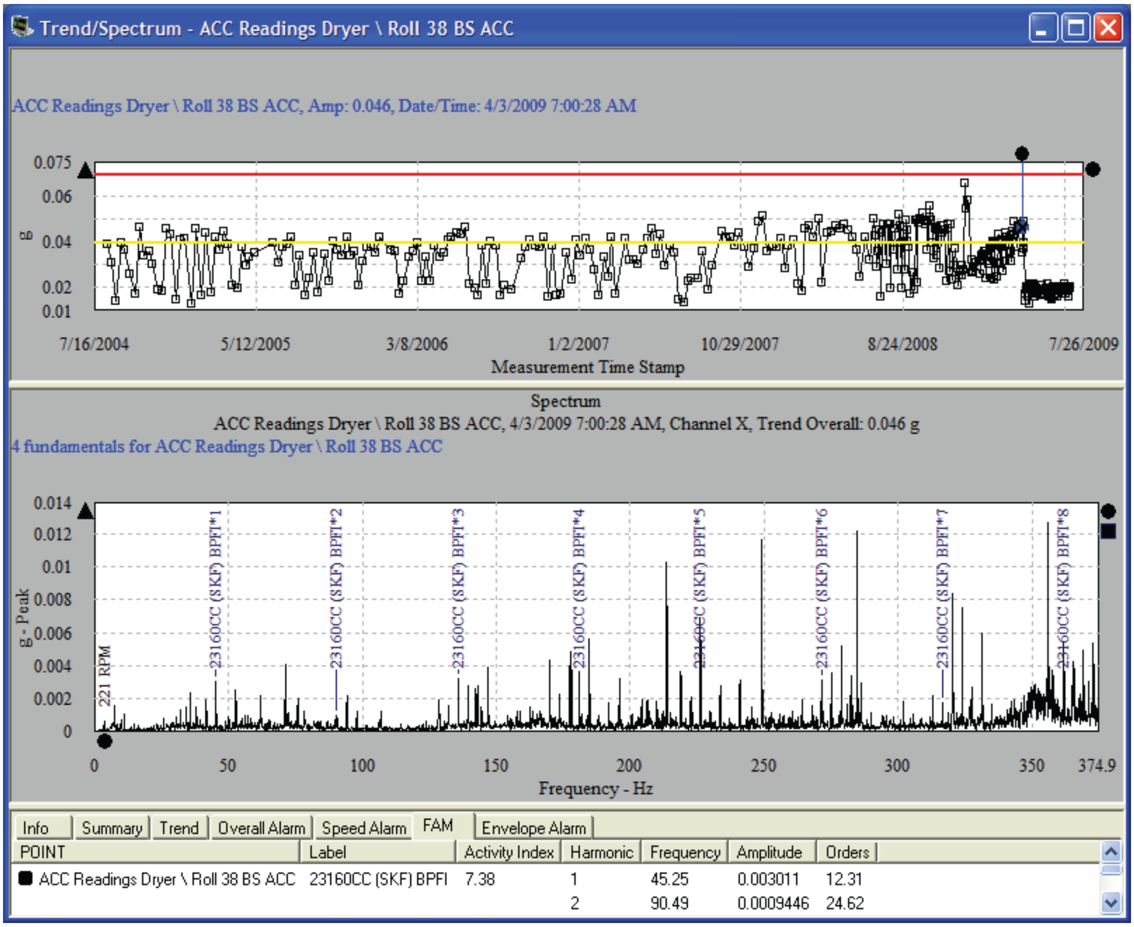


Figure 2. Spectrum/Trend combination plot showing development of a bearing defect.

Example application of HAL in a dryer cylinder

This example shows how a derived POINT with a HAL function provides early indication of bearing damage in a paper machine's dryer cylinder. The dryer cylinder is fitted with accelerometers mounted at both the front side and back side, in the axial direction. Both sensors are configured for an acceleration measurement and an acceleration enveloping measurement (filter 3). The exampled, combined spectrum/trend display captured over several years shows an increased acceleration reading level towards the end. The spectrum captured just before bearing replacement shows a clear inner race (BPFI) pattern. The detection of this bearing damage development was due to diligent work of maintenance personnel who reviewed every single spectrum on a daily basis.

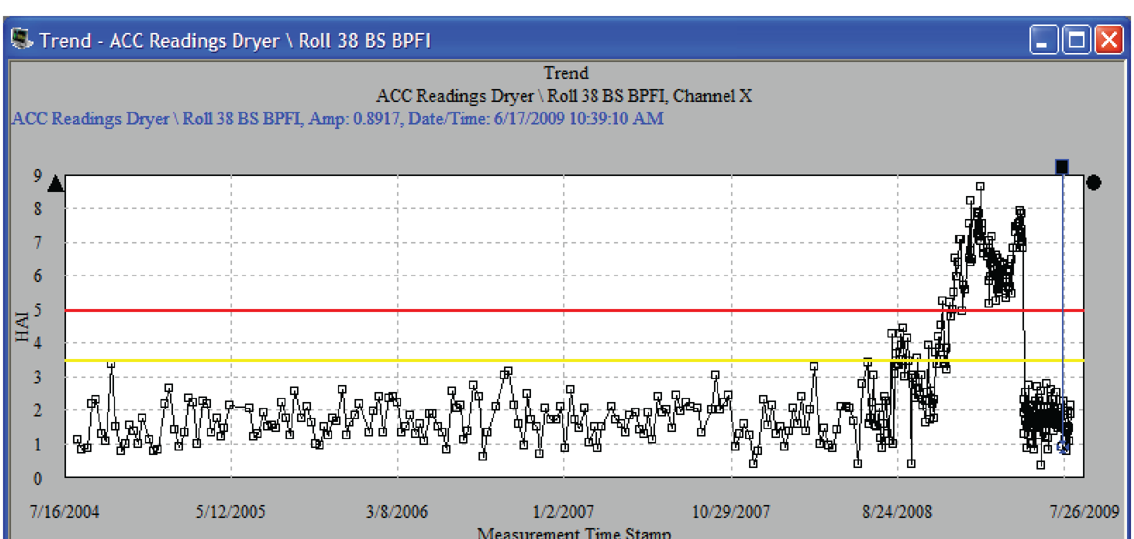


Figure 3. BPFI – HAL index trend.

Important to notice is that the BPFI pattern is evaluated by the HAL function to have an index of more than 7; a good confirmation of a clear harmonic pattern. Using SKF @ptitude Analyst's derived POINT functionality, two derived POINTs were created; one using the BPFI speed multiple and one using the BPFO speed multiple. The resulting trends are shown in **Figures 3 and 4**.

In comparison to the acceleration measurement's trend, the bearing fault's development is more clearly determined by observing the HAI trends as shown in **Figures 3 and 4**. In addition, the earliest indicator of the damage occurs much earlier in the HAI trends.

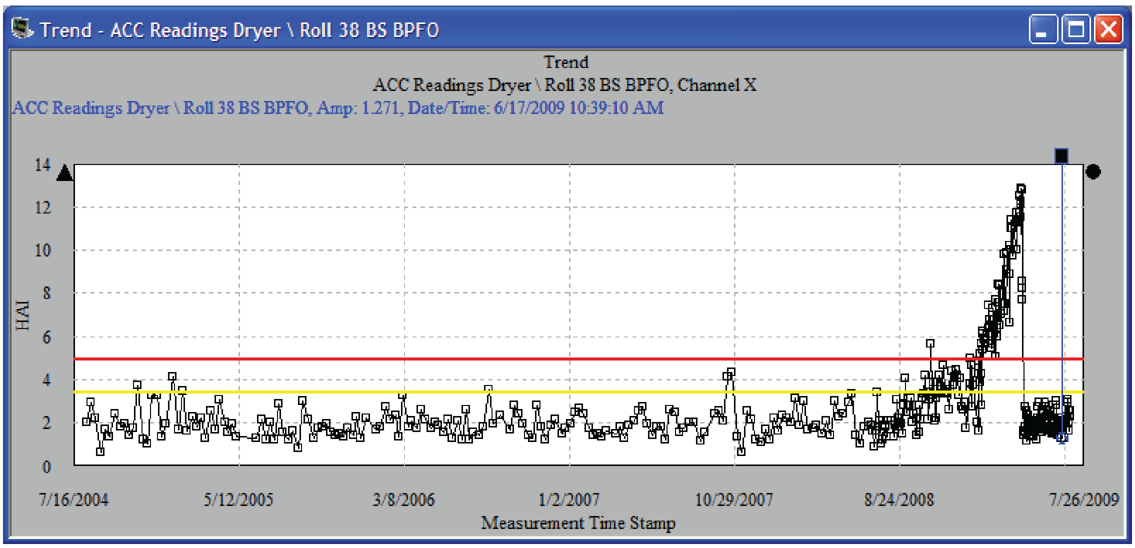


Figure 4. BPFO – HAL index trend.

The POINT properties for these derived POINTs are shown in **Figure 5**.

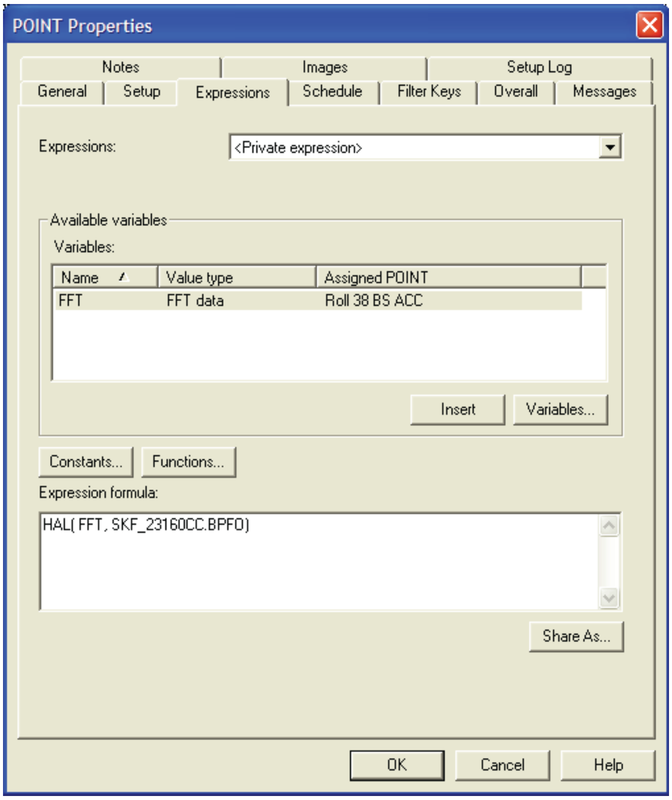


Figure 5. POINT properties for derived POINT with BPFO HAL calculation.

The derived POINT to compute the BPFO HAL trend simply lists the HAL() function taking "FFT" and "SKF_23160CC.BPFO" as its parameters. "FFT" is a variable and its association to "Roll 38 BS ACC" is listed just above the function. The variable association is created by pressing the "Variables..." button.

"SKF_23160CC.BPFO" is a constant definition and is simply a handy shortcut to remember the actual BPFO bearing multiple value of 9.6649. This value can be entered in the HAL function directly, but entering it as a constant value makes it available to other derived POINTs. It is also easier to maintain and simpler to read. To create a constant for derived POINTs, access the @ptitude Analyst Constants menu through Customize/POINT Attributes/Derived POINTs and select the "Constants" tab.

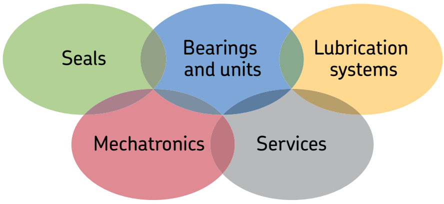
Combining HAL Trends

Creating HAL trends through a derived POINT may leave you with many extra POINTs. Though these are automatically updated as soon as a new measurement result arrives, it does require someone to take a look at the trend. It is possible to combine, for example, the BPFO and BPFI trends into a single trend that simply trends "bearing failure." To combine HAL index values from two or more trends, use the MAX() function. Using the example from above, the formula for the combined BPFO and BPFI trend would be:

MAX(HAL(FFT, SKF_23160CC.BPFO), HAL(FFT, SKF_231609CC.BPFI))

You can extend this concept to include all bearings from a single machine, and thereby create a trend that tracks bearing damage for that machine, regardless of which particular bearing has the fault.

Notice that you should use the MAX() function and not simply create an average of all the HAL() index values. Averaging would not allow a single increasing HAL index to push up the trend enough to be noticed, or to break through an alarm threshold.



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