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Knowledge Base Article

Product Group: Software
Product: CMSW7400 - @ptitude Analyst
Version: 4.1 or greater

Abstract

The purpose of this document is to educate the user regarding Harmonic Activity Index (HAI). The HAI will be defined and the process explained.

Overview

Software requirements

- Aptitude Analyst 4.1 or greater

Hardware requirements

- Not Applicable

Definitions

Harmonic	A harmonic frequency is a frequency that is an integer multiple of a given fundamental frequency. This fundamental frequency could be sub-synchronous, synchronous, or non-synchronous.
Impact	"Pulse-like" signal such as a bearing defect that produces a series of harmonic frequencies.
Order	An expression of frequency which relates a frequency (f) (subsynchronous, synchronous or nonsynchronous) to shaft running speed (RPM). It is calculated using the formula: Order=f/RPM. In order analysis, the frequency axis of the spectrum is expressed in orders of shaft RPM (i.e. peaks may be referred to as 1xRPM, 2xRPM, 4.33xRPM or 0.44xRPM).
Spectrum	A method of viewing the vibration signal, also called a Fast Fourier Transformation (FFT). In non-mathematical terms, this means that the signal is broken down into specific amplitudes at various component frequencies.

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Introduction
Harmonic Activity Locator (HAL) is a tool that mimics the actions of an experienced vibration analyst in investigating vibration data for harmonic activity indicative of impulsive characteristics in a vibration spectrum. In @ptitude Analyst 4.1 the HAL method is now available and its output, Harmonic Activity Index (HAI), is shown on the spectrum plot in the Harmonic overlay, Frequencies overlay, and the new Diagnostics overlay. Table 1 below lists typical machinery defects and the suitability of HAI as a diagnostic tool.

Defect	Symptom	Candidate for HAI
Imbalance	A single spectral peak at running speed.	No
Resonance	A single spectral peak at the structural resonance frequency	No
Mechanical Looseness	Harmonic series with fundamental frequency at running speed	Yes
Misalignment	Harmonic series with fundamental frequency at running speed	Yes
Rotor Rubbing	Harmonic series with fundamental frequency at half of the running speed	Yes
Bearing Damage	Harmonic series with fundamental frequency at one or more bearing defect frequency	Yes
Electrical Defects	Harmonic series with fundamental frequency at one or more electrical defect frequency	Yes
Gear Defects	Harmonic series with fundamental frequency at gear mesh defect frequency	Yes

Table 1. Selected Mechanical Problems and their Expected Spectral Features.

How Does the HAL Algorithm Detect a Harmonic Series?
The HAL algorithm as implemented in @ptitude Analyst first converts normalizes the spectra to an internal standard so that spectra with different measurement units or sensor type result in similar HAI values. HAL then searches throughout the spectrum for potential harmonic content.

HAL takes each identified peak that is potentially the fundamental frequency of a harmonic series, finds its harmonic frequencies, and averages the amplitudes at these frequencies. The harmonic average amplitude is then divided by the average of all of the non-harmonic

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spectral line amplitudes to result in the HAL index number, HAI. For example, if the spectrum were perfectly flat, the HAL index would be 1.

In @ptitude Analyst, this calculation is done regardless of the machinery defect attributes (bearing type, vanes, etc…) assigned to the machine. The user is able to view the HAI for each machinery defect attribute assigned to the point through the frequency plot overlay.

Due to the normalization process, the HAL index is non-dimensional and independent of absolute vibration amplitude, focusing specifically on the pattern defined by the appearance of spectral peaks that are harmonically related. This particular feature of the HAL algorithm enables a universal alarm threshold for detecting harmonics series, independent of the spectrum measurement domain or location and orientation of the sensor. SKF Reliability Systems has processed hundreds of thousands of spectra through the HAL algorithm. Based on extensive empirical review, SKF Reliability Systems has determined that a HAI below 2.5 provides a low level of confidence in the presence of harmonic activity, and an index above 3.5 provides a high level of confidence in the presence of significant harmonic activity associated with the evaluated fundamental frequency. Used as a screening tool, all spectra with a HAI of greater than 2.5 should be reviewed for significant mechanical problem indications, whereas spectra with a HAI below 2.5 can most likely be skipped by the analyst, when no other screening method (such as band alarms) indicates a problem.

HAL adds a significant new way of looking at spectra to find evidence for mechanical defects. It simplifies the search for these by presenting a simple, dimensionless value. However, HAL should not be seen as the only tool one looks at but rather to compliment the existing ones by adding a level of automation and simplification.

Implementation of HAL Algorithm

Currently, HAL is available in:

- @ptitude Analyst - Human Machine Interface (HMI)
- @ptitude Decision Support
- @ptitude Analyst version 4.1+
- CMVA65 Microlog

This paper will focus on the use of HAI in @ptitude Analyst 4.1. However, a quick review will be given of the use of HAL in all three SKF software applications.

@ptitude Analyst Human Machine Interface (HMI)

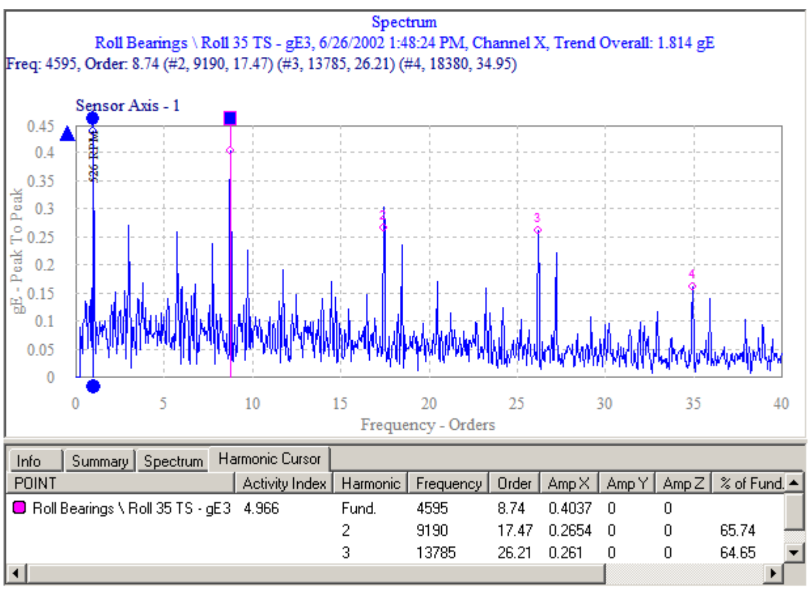
The @ptitude Analyst /HMI software is a supporting application for SKF’s @ptitude Analyst™ application. With the HAL algorithm implemented, the software allows the user to specify rules for applying HAL to individual points that have FAM (Frequency Analysis Module) information in the @ptitude Analyst database. Users can trend the HAL index and use HAL to automatically process an entire database to pick out any measurement that has harmonic series in the spectrum. Users can turn on or off any particular measurement at any point for HAL index computation, and set HAL alarm levels (Low confidence index, High confidence index).

@ptitude Decision Support

HAI is calculated and used in @ptitude Decision Support software as a Harmonic Frequency key feature. The algorithm calculates the value of HAL and then uses this value in the Asset Knowledge Science methodology for identifying faults present in the machinery assets.

@ptitude Analyst

With the release of @ptitude Analyst 4.1, the Harmonic Activity Index can be viewed in the spectrum plot Info Area, in the plot overlays for Harmonic Cursor, Frequencies, and the new Diagnostic Cursor. The plots below are taken from an Enveloped Acceleration reading collected on a Paper Machine Roll showing an inner race defect on the tending side bearing. It can be seen that there are slight differences in the Harmonic Activity Index that are attributable to the bandwidth that the three overlays use when calculating HAI. For example, the Harmonic Cursor overlay requires the user to “tune” to the frequency of interest and the software calculates a HAI as the cursor is moved. The Frequencies overlay only calculates HAI on frequencies identified for the point. The Diagnostic cursor examines the entire spectrum and ranks the highest frequencies identified.



POINT	Activity Index	Harmonic	Frequency	Order	Amp X	Amp Y	Amp Z	% of Fund.
Roll Bearings \ Roll 35 TS - gE3	4.966	Fund.	4595	8.74	0.4037	0	0	
		2	9190	17.47	0.2654	0	0	65.74
		3	13785	26.21	0.261	0	0	64.65

Figure 1. Harmonic Cursor Overlay on Spectrum Plot

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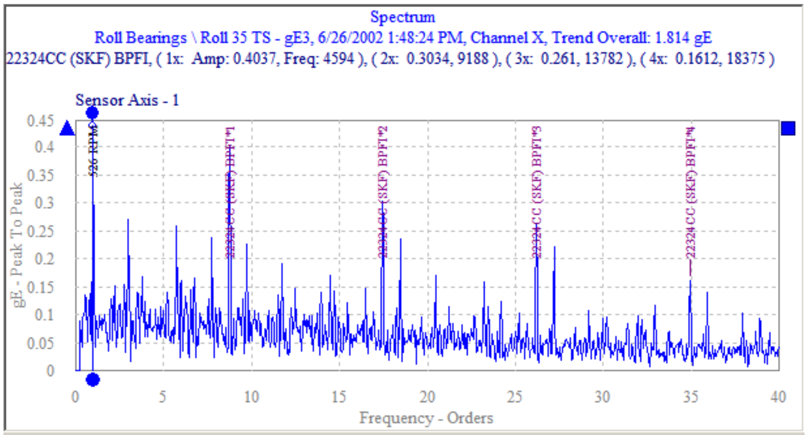
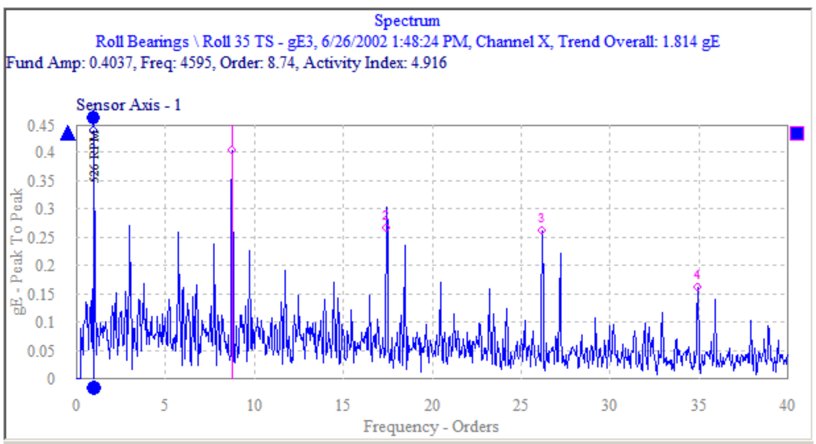


Info | Summary | Spectrum | FAM

POINT	Label	Activity Index	Harmonic	Frequency	Amplitude	Orders
Roll Bearings \ Roll 35 TS - gE3	22324CC (SKF) BPFI	4.869	1	4594	0.4037	8.735
			2	9188	0.3034	17.47
			3	13782	0.261	26.21
			4	18375	0.1612	34.94

Figure 2. Frequencies Overlay on Spectrum Plot



Info | Summary | Spectrum | Diagnostics

POINT	Index	Activity Index	Frequency	Order	Information
Roll Bearings \ Roll 35 TS - gE3	1	4.916	4595	8.738	22324CC (SKF) BPFI
	2	3.808	1021	1.941	

Figure 3. Diagnostic Cursor Overlay on Spectrum Plot

One final point in the configuration of HAI is the Diagnostic Percentage setting. shown below in the Customize/Preferences/Plot Settings.

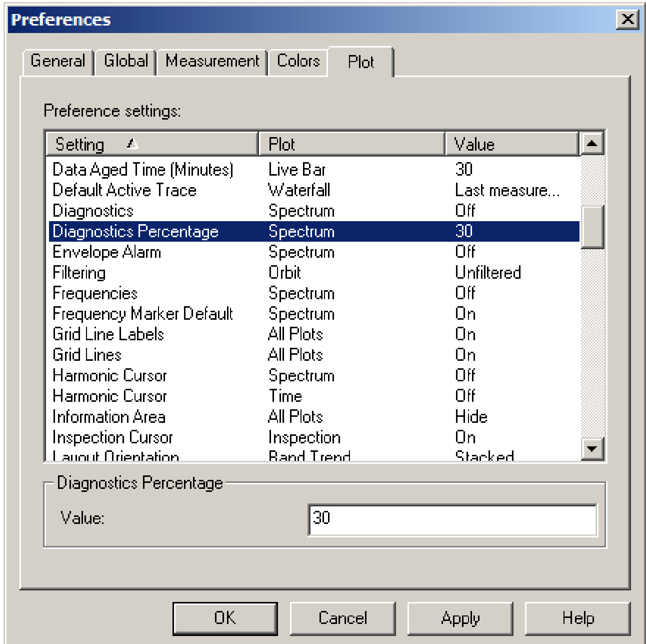


Figure 4: Diagnostic Percentage in the Preferences Dialog

This setting only affects the Diagnostic Cursor overlay. The Diagnostic Percentage sets the threshold level at which HAI indices will be displayed, based on a percentage of the highest Activity Index detected in the spectrum. For example on the plot illustrated above, showing a HAI of 4.916, with the default setting of 30% for Diagnostic Percentage, only HAI values above 3.441 (4.916*(1-0.30)) will be displayed. If the Diagnostic Percentage is changed to 80%, then HAI values above 0.983 (4.916*(1-0.80)) will be displayed as illustrated below.

POINT	Index	Activity Index	Frequency	Order	Information
Roll Bearings \ Roll 35 TS - gE3	1	4.916	4595	8.738	22324CC (SKF) BPFI
	2	3.808	1021	1.941	
	3	3.399	1575	2.995	
	4	3.303	1149	2.185	
	5	3.286	918.7	1.747	
	6	3.114	9192	17.48	
	7	2.962	1970	3.745	
	8	2.929	2297	4.368	
	9	2.817	1314	2.499	
	10	2.577	3063	5.824	
	11	2.560	4069	7.737	
	12	2.420	1707	3.245	
	13	2.328	1837	3.494	
	14	2.281	1444	2.746	22324CC (SKF) BSF
	15	2.256	5119	9.734	
	16	2.226	3576	6.8	
	17	2.138	3445	6.551	
	18	2.077	2756	5.24	
	19	2.026	2888	5.492	
	20	2.023	3321	6.315	22324CC (SKF) BPFO

Figure 5: Diagnostic Overlay with increased Diagnostic Percentage

The Diagnostic Percentage allows the user to raise or lower the bar at which HAI are displayed.

The advantages of using the HAL algorithm are illustrated in the following case histories.

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Case History 1
USE OF HAI ON A LARGE GEARBOX

The pinion drives a drying kiln. There are 24 teeth on the pinion gear resulting in a gear mesh of 24 x RPM. The bearing is an SKF 23152CC with BPFO 9.19, BPFI 11.81, BSF 3.87, FTF 0.438. The speed of the pinion is approximately 52 RPM.

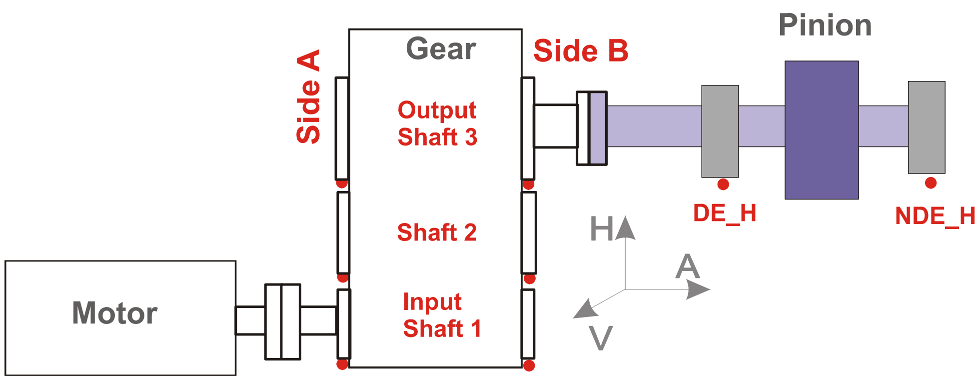

Figure C1-1: Schematic of Gearbox

High vibration was found during routine route collection. HAI was used as a tool to investigate the source. The primary suspects were the gear and the bearing. In investigating the spectrum, it is found that there are many harmonics present in the spectrum. HAI is correspondingly high, and can be seen in Figure C1-2 to be above 25 in using the Harmonic Cursor overlay.

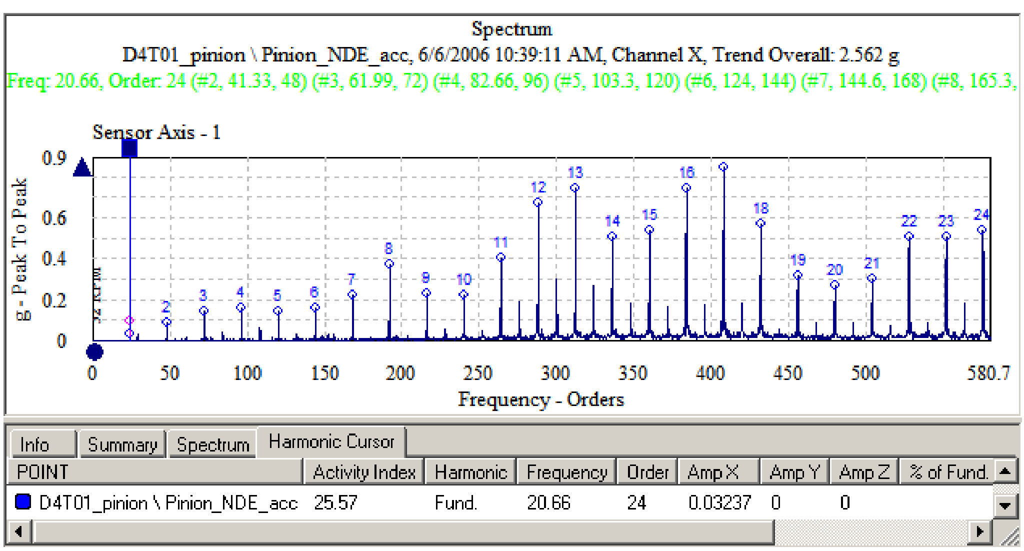

Figure C1-2 – Acceleration Spectrum for non drive end of Pinion (NDE) – Harmonic overlay

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Using the Diagnostic overlay, in Figure C1-3a, both the Gear Mesh and the Bearing Inner Race defect (BPFI) frequency are identified above the alert level of 2.5. This is slightly misleading, because the BPFI frequency is roughly ½ of the Gear Mesh frequency, combined with the presence of half order harmonics at higher frequency leads to the BPFI falsely showing a high level of HAI.

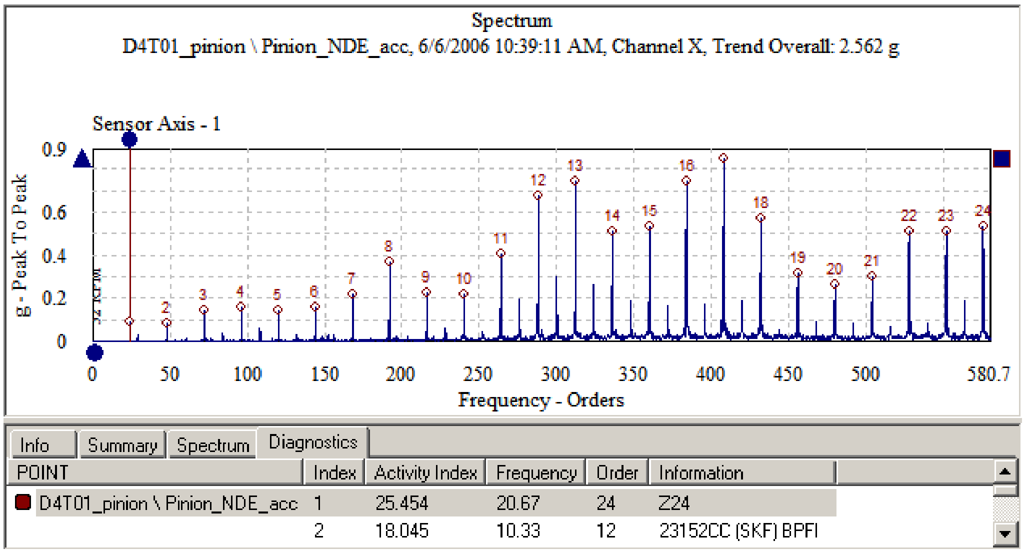

Figure C1-3a – Acceleration Spectrum for non drive end of Pinion (NDE) – Diagnostic overlay – Gear Mesh frequency highlighted

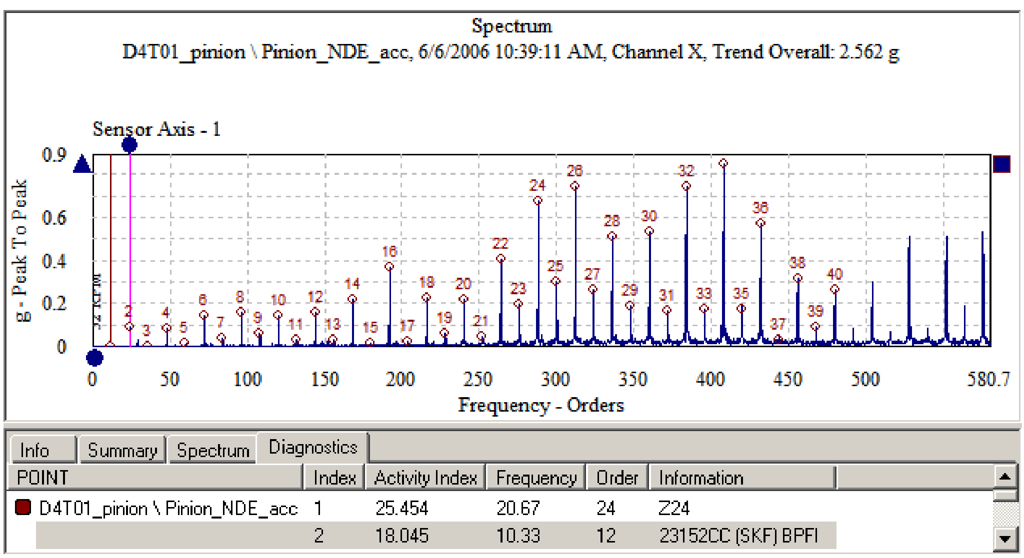

Figure C1-3b – Acceleration Spectrum for non drive end of Pinion (NDE) – Diagnostic overlay - BPFI highlighted

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The Gear Mesh defect is further confirmed when looking at the Profile plot from the SKF's Human Machine Interface. This plot clearly shows 24 impacts in the profile, indicating a defect in the gear.

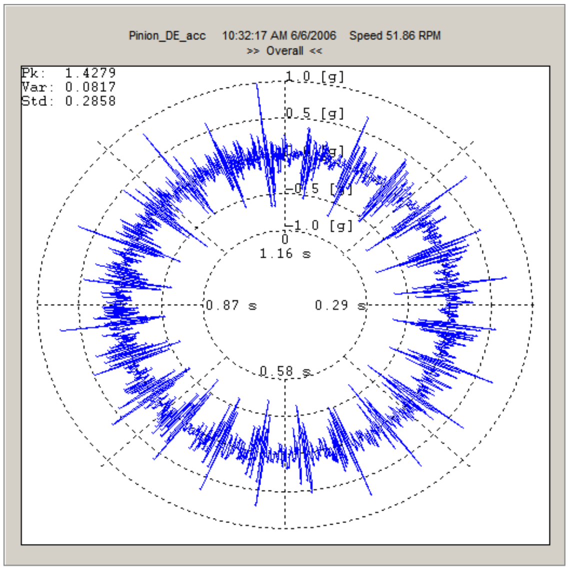

Figure C1-4 – HMI Profile for non drive end of Pinion (NDE)

The conclusion is that the source of vibration is the Pinion gear mesh and the bearing is in a good condition. The customer decided to change the bearings, but GMF was still present after the change and therefore the problem was in the gears.

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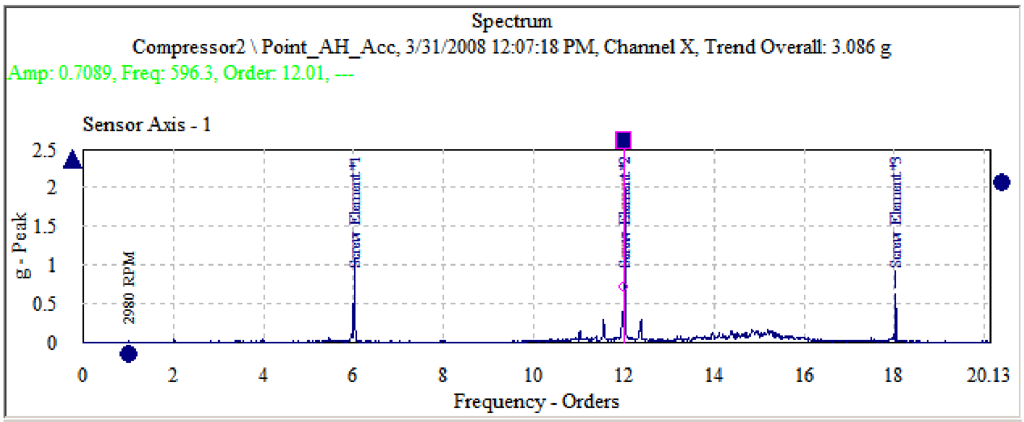
Case History 2

USE OF HAI ON A SCREW TYPE COMPRESSOR

HAI was used to identify a compressor flow issue. As seen in the Frequencies overlay in Figure C2-1, HAI is highest at the Screw Element frequency of 6xRPM. The HAI shows a clear indication of the defect in the compressor.



Info | Summary | Spectrum | FAM

POINT	Label	Activity Index	Harmonic	Frequency	Amplitude	Orders
Compressor2 \ Point_AH_Acc	Screw Element	10.23	1	298.4	1.076	6.009
			2	596.9	2.272	12.02

Figure C2-1 – Acceleration reading on Compressor

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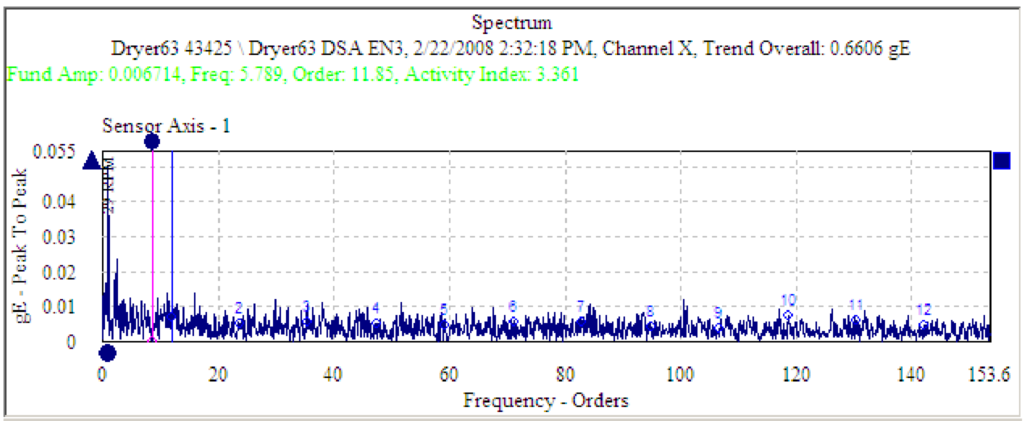
Case History 3
USE OF HAI ON A DRYER ROLL FROM A PAPER MACHINE

Due to a product change on the paper machine, the speed of the roll was reduced from 100 to 25 RPM. The machine is very slow and loads are light on the bearings, therefore it takes a long time for fatigue bearings failures to occur. In reviewing past failures of the bearing, the usefulness of HAI can be clearly seen. The gE reading often contains many frequencies that can be hard to distinguish. HAI has automatically worked through the spectrum and identifies bearing defect frequencies of the inner race and the ball spin frequency. This bearing, shown in Figure C3-2, was found to be defective when replaced. These frequencies would be very difficult to find and distinguish without the use of HAI as seen in Figure C3-1. HAI however, is capable of distinguishing the harmonic content and shows an HAI value of 3.361.



Info | Summary | Spectrum | Diagnostics

POINT	Index	Activity Index	Frequency	Order	Information
Dryer63 43425 \ Dryer63 DSA EN3	1	3.463	1.651	3.382	22238C (SKF) BSF
	2	3.361	5.789	11.85	$ BPFI 11.75

Figure C3-1 – Acceleration Envelope reading on Dryer Roll Dryer Side Bearing

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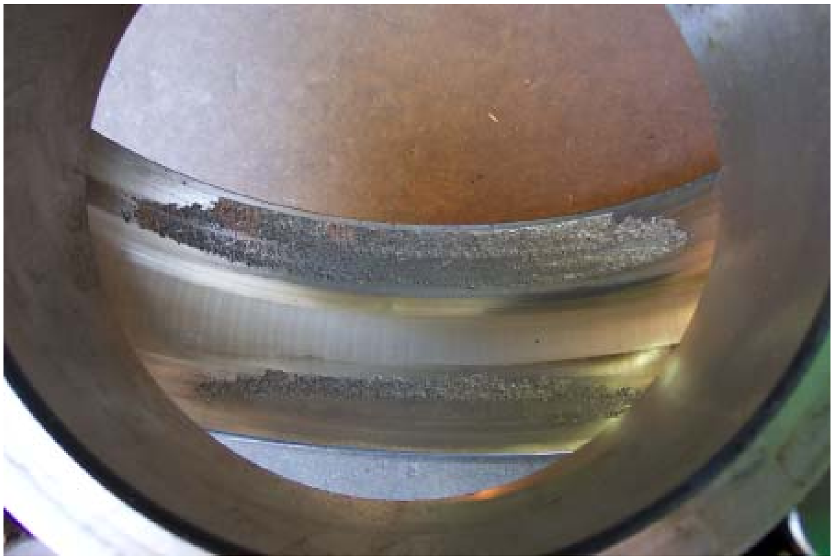

Figure C3-2 – Drive Side Bearing after removal

Conclusion

The HAI algorithm is a powerful tool for detecting and confirming harmonic activity in a spectrum. The fact that its alarm threshold has nothing to do with absolute amplitude of the measurement makes it a simple tool to relieve the analyst of the need search for difficult-to-see harmonic activity. The implementation of the HAL algorithm in SKF's @ptitude Analyst software provides easy access to this tool.