The Evolution of PeakVue™ Processing – PeakVue Plus Analytics

PeakVue has long been recognized as the premiere technology for detecting rolling element bearing defects. Since its release in 1995, PeakVue applications have continually expanded to cover new areas of machinery health monitoring and analysis. PeakVue Plus Analytics take PeakVue a step further to provide prescriptive analytics.

Introduction

The peak value analysis (PeakVue) methodology introduced by Emerson for the analysis of impacting on machines has long been recognized as the premiere tool for identifying bearing defects.

The Evolution of PeakVue

The Expert's Tool: First released in 1995, PeakVue processing quickly became the expert's best tool for diagnosing rolling element bearing defects. It had the ability to visualize the impacts caused by bearing defects in the frequency spectrum more clearly than ever before. In the example in Figure 1, despite the relatively low level amplitude of impacting, the peaks are clearly visible in the PeakVue spectrum. In the corresponding demodulation spectrum, the peaks associated with the defect would be lost in the "noise" providing little or no indication of an actual defect being present.

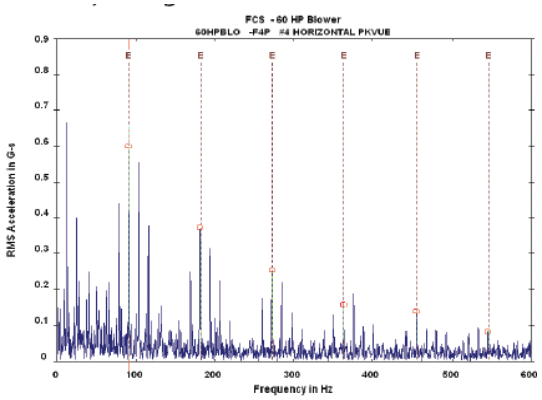

Figure 1 - PeakVue Spectrum showing clear indication of bearing defect frequencies

In fact, PeakVue was able to identify a defect during the initial stage of a developing fault when there was only sub-surface deterioration – or weakening - of the bearing metal, but without any visible sign of bearing wear to the human eye. This forced end users to delay their recommendation for bearing maintenance.

At this point in time, however, PeakVue remained "the expert's tool" as it took special knowledge and training to properly set up the acquisition parameters

Automated Set-up: To address the complexity of setting up a PeakVue measurement and to increase accessibility to this innovative new technology, an automated configuration module was implemented as part of the Analysis Experts (Figure 2). First introduced in the CSI 2120, the "Bearing and Gear Analysis" application is still available as part of the AMS 2140. This feature allows end users to execute complex measurements using PeakVue processing with little or no training in advanced vibration techniques. At the touch of a button, the unit automatically configures the acquisition parameters, opening up access to the power of PeakVue processing to all end users.

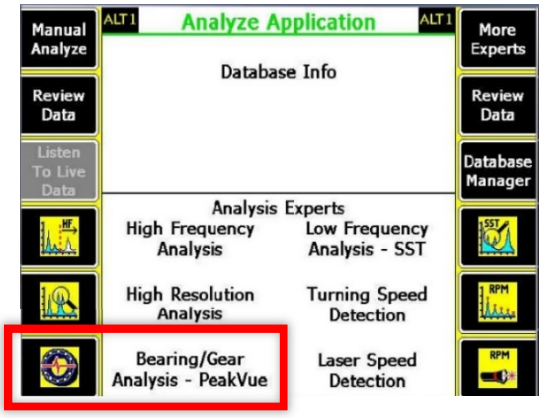

Figure 2: PeakVue Analysis Expert

PeakVue Waveform: While PeakVue provided superior results in the frequency spectrum, its usefulness was not limited to the vibration spectrum. PeakVue also provides valuable diagnostic information in the waveform. This made it unique and more powerful than other techniques as some defects simply can't be detected in the spectrum (e.g. very low speed bearing faults, broken gear tooth, etc.).

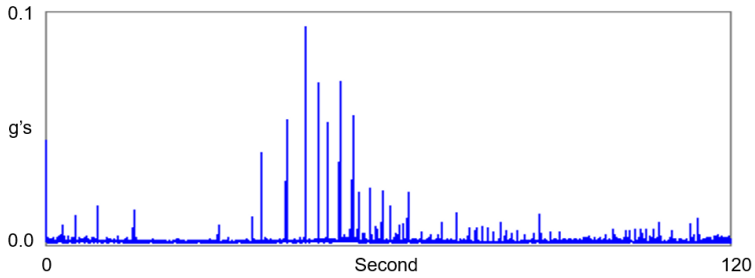

Figure 3 - PeakVue waveform showing inner race defect on shaft turning at 1/2 RPM

Figure 3 shows impacting from an inner race defect that occurred a shaft turning at slower than 1 RPM. This type of defect cannot be effectively identified in the spectrum due to the long collection time and the relative fluctuations in the turning speed. Further, the amplitude of the impacting (less than 0.1 g's) would be further diminished in the spectrum, so that it would fall below the signal to noise threshold. Instead, we have a clear picture of the actual signal caused by the inner race damage. The impacting increases significantly (10X) as the defect passes through the load zone, and then fall back down to extremely low levels.

PeakVue as Trend Parameter: In 2010, as PeakVue readings were first broadcast into the control room, it became clear that the PeakVue "overall" provided one of the most valuable trend parameters for monitoring machine health. The trend of the peak value in the PeakVue waveform correlates directly to the health of the bearing. Figure 4 shows a trend of the overall vibration (blue line) on a machine as the bearing progresses to failure. The blue line appears to fluctuate randomly without providing any indication of the impending production shutdown. In comparison, the PeakVue trend (red line) indicates the onset of the failure around Nov. 28th as it lifts off its baseline and shows a steady increase in the trend value – reaching about 40 g's before the bearing fails on Dec. 11th.

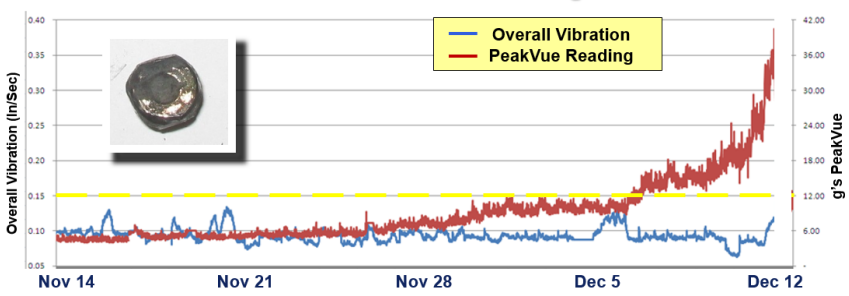

Figure 4 – PeakVue trend (red) show clear indication of a developing fault as a bearing progresses to failure, while Overall Vibration (blue) provides no indication.

As an initial premise for operators to interpret the PeakVue trend, we can assert that the PeakVue value on a good machine - properly installed and well lubricated - should be at or close to zero. This became known as the "Zero Principle", and it allowed an operator to verify easily that the bearing and lubrication on a machine were operating within normal limits.

For most process equipment (e.g. machines with turning speeds between 900 and 4000 RPM), once the PeakVue value has reached a level of 10 g's, it is an indication that there is an abnormal situation on the bearing. Furthermore, the PeakVue value increases steadily as the bearing condition deteriorates. This led to the development of the "Rule of 10's" for monitoring most process equipment, which is summarized in Figure 5. It states that when the PeakVue value measured in g's Peak reaches the level of 10, that here is an

PeakVue Value *(g's Peak)*	Interpretation
0	Good machine
10	Abnormal Situation
20	Serious Abnormal Situation
40	Critical Abnormal Situation

Figure 5 - Rule of 10's

abnormal situation on the bearing. If it doubles to 20, then it becomes a serious abnormal situation. If it continues to double to 40, then it has become a critical abnormal situation. Apply the "Zero Principle" and the "Rule of 10's", an operator with no vibration training is now able to identify the following aspects of machine condition:

- Know when the machine is healthy
- Detect the presence of a machine defect
- Monitor the severity of the defect

PeakVue Plus Analytics: The latest evolution of this ground-breaking PeakVue technology is referred to as "PeakVue Plus Analytics". This innovative approach mimics the process that an analyst would apply to determine the nature of an abnormal situation, once it has been identified on a machine based on the PeakVue level. At a high level, machine faults can be categorized as mechanical or non-mechanical. Mechanical faults are caused by defects in rolling element bearings or gears, and the signals they generate are highly periodic. In contrast, non-mechanical signals are typically the result of under-lubrication of the bearing (or potentially cavitation on pumps). The signals generated by under-lubrication are non-periodic – or random – in nature. A trained analyst would employ a technique called "Autocorrelation" to distinguish between these two types of defects. In a similar manner, PeakVue Plus Analytics applies autocorrelation and series of sophisticated algorithms to determine the root cause of the defect on a given machine.

Autocorrelation: The statistical technique called autocorrelation is a means of identifying the amount of periodicity in a given signal. While this value is not tremendously helpful when applied to traditional vibration, it is extremely useful when analyzing machine impacting as measured by PeakVue technology. The autocorrelation of a signal will typically return values between zero and one. Values around zero indicate a high level of randomness in the signal, while values above 0.25 start to indicate periodic or mechanical impacting.

Figure 6 shows the correlation of 2 different signals. Both signals contain significant impacting, such that a recommended course of action is in order. The autocorrelation values for the signal on the left hover

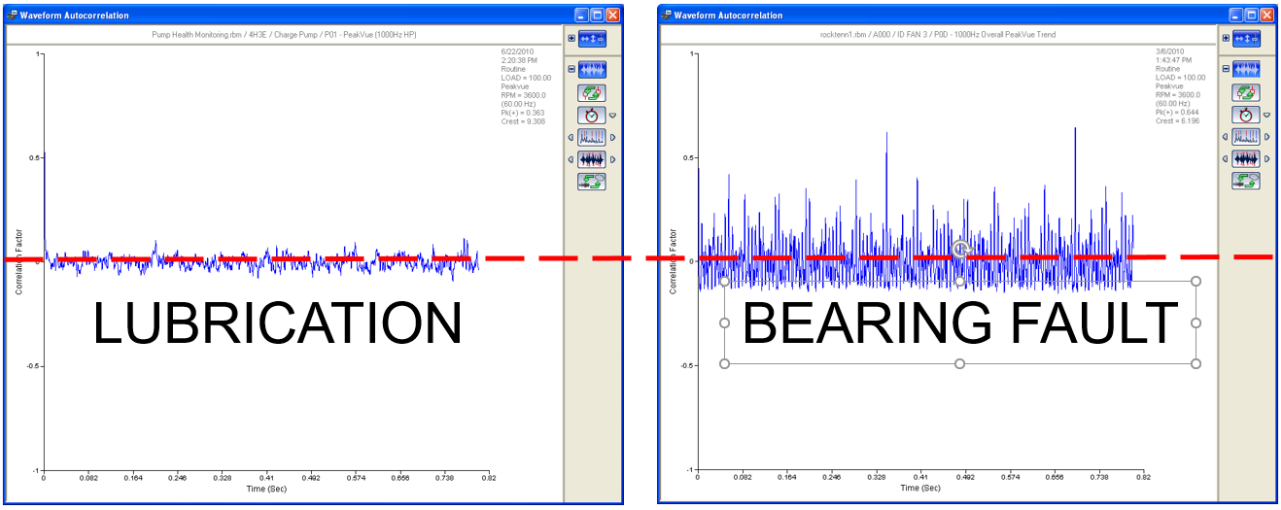

Figure 6 - Autocorrelation of a lubrication defect (left) and a bearing fault (right).

around zero and shows no visible pattern. This is the result that is expected when the root cause is insufficient lubrication. Conversely, the autocorrelation values for the signal on the right show a clear repeating pattern, and the amplitudes extend up above 0.5. This indicates a high level of periodicity as would be expected with a rolling element bearing defect.

Combining this principle with the ability of PeakVue to identify an abnormal condition has resulted in the new capability referred to as "PeakVue Plus". This can be easily employed to determine the root cause of the defect at the touch of a button. This technology has been implemented in the AMS 2140 as a new Analysis Expert as shown in Figure 7.

To establish the severity of a defect, it is important to first establish the turning speed of the shaft. This is the key value that is used to determine the appropriate limits for the PeakVue amplitudes. In general, the higher the turning speed, the higher the alert limit.

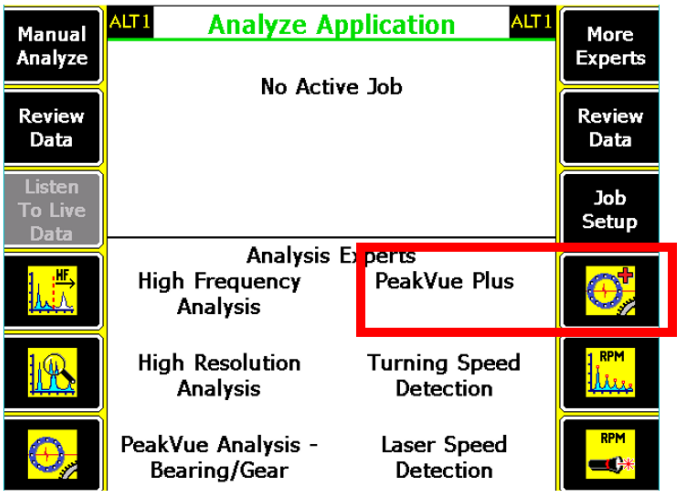

Figure 7 - New PeakVue Plus Analysis Expert

When launching PeakVue Plus Analytics from a Route point in the AMS 2140, the turning speed of the route point will be used as basis for the alert limit calculation. When launching the from the Analyze application, however, it is necessary to input or measure the turning speed of the machine before you can proceed with the analysis.

The algorithm uses the turning speed to determine the alert level for the PeakVue impacting on the machine, and then it uses autocorrelation together with a sophisticated algorithm to automatically identify the root cause of the impacting. These values are combined to determine the likelihood of a mechanical or lubrication defect on the machine. Figure 8 shows the output of the PeakVue Plus Analytics for a machine with a bad bearing.

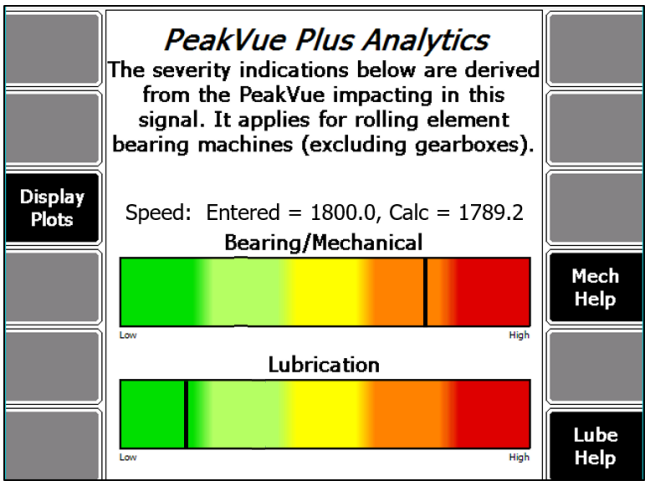

Figure 8 - Results from PeakVue Plus Analytics in the AMS 2140

A simplified representation of the logic used to determine the nature and extent of a machine defect is shown in Figure 9. In general terms, as the amplitude of the PeakVue impacting increases, if the Periodicity is low, then it indicates a high likelihood of a lubrication defect on the machine. Conversely, if both the amplitude and the periodicity of the PeakVue impacting are high, then this indicates a high likelihood of a mechanical defect such as bearing or gear wear.

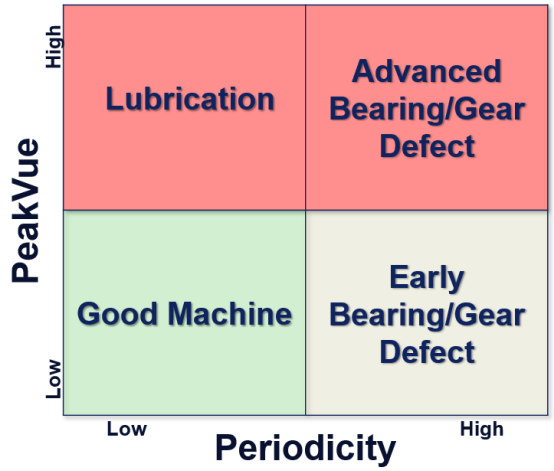

Figure 9 - Simplified Model for PeakVue Plus Analytics

When there is a significant increase in periodicity without a significant increase in the PeakVue impacting, this is an early sign of mechanical wear.

For a good machine with no defects, both the PeakVue impacting and the Periodicity of the PeakVue signals should be very low.

By identify the nature and severity of the defect, PeakVue Plus Analytics also *prescribes* the appropriate action to address the defect. In this way, PeakVue Plus Analytics takes the AMS 2140 beyond Predictive and Proactive Maintenance to *Prescriptive* Maintenance.

Additional Considerations: As with any system for automated diagnostics, it is important to consider additional factors to verify the result. The implementation of PeakVue Plus Analytics in the AMS 2140 offers on-board help as follows:

Mechanical Defects: Aside from a rolling element bearing defect, other potential conditions that could be flagged as a mechanical defect include:

- If the machine train includes a gear, check for possible gear wear.
- On variable speed equipment, ensure that the RPM is correct. An incorrect entry for the RPM of the machine may lead to an incorrect result.
- If there is significant vibration on a neighboring machine, it may be transferred through the foundation so that it registers at the actual measurement location on the suspect machine. This may in certain situations be identified as a mechanical defect. Repeating the analytics on neighboring machines prior to scheduling maintenance will eliminate this possibility. It is also an option to repeat the analytics on the suspect machine after shutting it down for maintenance. If the result remains the same, then the defect is actually based on the vibration from the neighboring machine.

Lubrication Defects: Random impacting can also occur with pump cavitation. If the suspect machine is a pump, please consider the possibility that the actual defect could be cavitation. When dealing with an actual lubrication defect, the result will remain constant regardless of the process configuration. In comparison, when a pump in cavitating, the result of the PeakVue Plus Analytics may change drastically together with changes in the process.

When used as intended, PeakVue Plus Analytics can be an effective part of a Prescriptive Maintenance program. For more information on the AMS 2140 or other Emerson products, please consult our website at www.emerson.com.

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