Monitoring Felt for Improved Paper Quality

Paper quality is significantly affected by the operating condition of components in the paper machine wet section. After the wet pulp leaves the front end wire section, the web still has high water content. The press section reduces the water content from 80% to 50%, when suction rolls apply pressure against the paper web, which is sandwiched between absorbent material or "felts". A felt is a long fabric, which may be grained in a variety of ways, a diagonal seam in this case, making a continuous loop. The felt carries the paper through the press nips, or roll contact points.

Whenever a felt seam becomes disjointed or uneven, a force impulse is generated as the seam passes through a nip. The impulse is large and causes the roll to bounce imperceptibly, often resulting in paper flaws. Further, bad rolls cause felt damage. In many instances, felts are continually replaced without correcting the underlying cause. This results in high maintenance costs, not to mention the resulting lost production and paper recycling costs.

Fig. 1. ***A papermill.***

In the past, these impulse forces were difficult and time consuming to detect, let alone to identify the faulty machine components causing them. The phenomenon creates a difficult measurement problem because it is characterized by a low signal to noise ratio, which is further attenuated by the structural path of the impulse. Further complicating the measurement problem is the low sensitivity of these low frequency ranges. Using a measurement technique known as synchronous time averaging enhances the coherent signal components associated with these forces, while non-coherent random noise is reduced to a zero average. Performing synchronous time averaging measurements requires the use of a reliable instrument trigger referenced to roll or felt rotational speed. The trigger must be able to operate in the harsh environment of the wet section while providing stable, repetitive trigger pulses. Each measurement cycle takes many minutes of averaging to discriminate between vibration caused by the roll (or felt) under observation and those that are not.

Synchronous time averaging is very useful to identify press vibrations that are sinusoidal and generated by eccentric, elliptical or corrugated roll surfaces. However, impulse signals resulting from roll flat spots, batt over and under laps, or bad felt splicing are best detected by enveloping demodulation techniques (acceleration enveloping). The causal machine component fault can then be further identified by the spectrum pulse repetition frequency.

SKF

In some paper mills, the use of acceleration enveloping has been successful in providing information for the optimal positioning and repositioning of the felt as the seam traverses the roll nips. The use of acceleration enveloping simplifies the act of making measurements, since it can be performed without a rotational trigger reference. Moreover, far fewer (to none) power averages are necessary than are required by synchronous time averaging. Therefore, the time to perform the detection, analysis and diagnosis are automatically reduced.

The SKF Multilog continuous monitoring system from SKF allows operators to make multi-parameter measurements at each sensor location. Both synchronous time averaging and acceleration enveloping measurements can thus be assigned to each channel through software configuration control. And acceleration enveloping can even be performed with synchronous time averaging.

A paper machine – case study

Operators at one major European paper mill, using an SKF Multilog multi-parameter continuous monitoring system, recently reported a very effective diagnosis of a felt fault using the acceleration enveloping technique. The papermill was experiencing paper quality degradation on one machine. It was suspected that the problem was caused by excessive vibration occurring in the press nip of the wet section. Based on previous measurement experiences, operators expected signal frequencies to be found below 1 Hz and that acceleration enveloping measurements would allow the display of signal responses to low frequency impacts, such as those resulting from a poorly spliced felt seam traversing the press nip.

Using the overall acceleration envelope value as the trend criterion, data was continuously collected over a two week interval. **Fig. 3** displays the overall acceleration envelope trend from 13 April to 29 April. It was apparent that there were problems in this section of the paper making process, since a sharp upward trend was evident along with a three fold increase in overall value. The envelope spectrum was analyzed (→ **fig. 4**) and further confirmed the hypothesis that a felt seam discontinuity was producing impact forces at the press nip under observation.

Fig. 4 clearly shows a harmonic series of peak amplitudes, spaced at the repetitive rate of the felt loop. Under ideal felt conditions, significant impacts would not be produced and neither the acceleration envelope upward trend nor the harmonic peak series spectrum would be present at such levels.

The diagnosis of a felt problem was conclusive. The felt was replaced and subsequent paper machine operation resulted in a considerable improvement in paper quality. Operators continued to collect data with the SKF Multilog system. One month later, a new acceleration envelope spectrum indicated a problem with the crown roll associated with the monitored press nip.

Fig. 2. SKF Multilog Local Monitoring Unit (LMU).

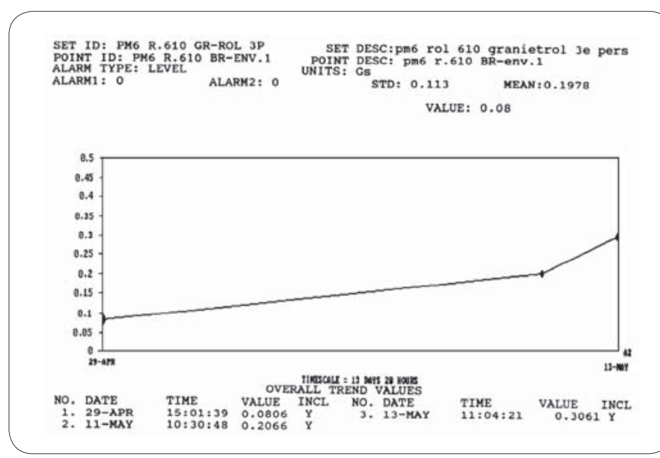


Fig. 3. Vibration acceleration enveloping overall trend.

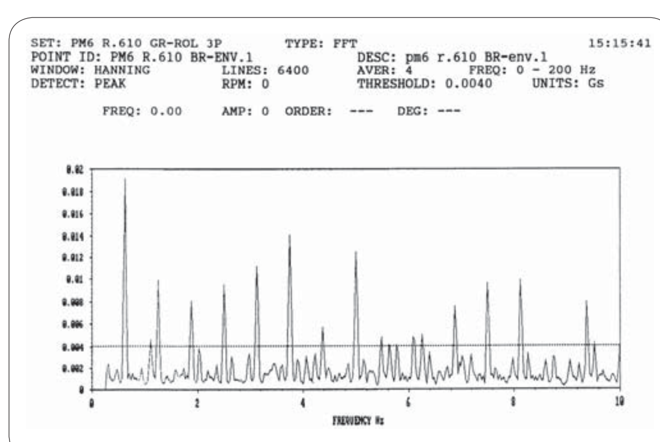


Fig. 4. Single spectrum plot – Acceleration enveloping spectrum indicating felt anomalies.

Fig. 5 shows a waterfall spectrum display of measurements taken on that date indicating a crown roll flat spot or out of round condition. Operators continued operation until ten days later, when again the felt problem signature appeared. At a convenient maintenance interval, both the crown roll and felt were replaced. Following these replacements, production continued normally without further incident.

Operators now report that they have introduced a new operating procedure, used to reposition the felt as related to the appearance of the felt signature spectrum. Felt washdowns are also scheduled based on the analysis of this vibration data.

Fig. 6 is an interesting trend diagram showing the overall acceleration envelope level of the same crown roll nip one year later. A higher than normal level is seen between 10 March to 24 March when the felt was replaced. Following that week, the lower overall trend provides a confirmation of normal operation.

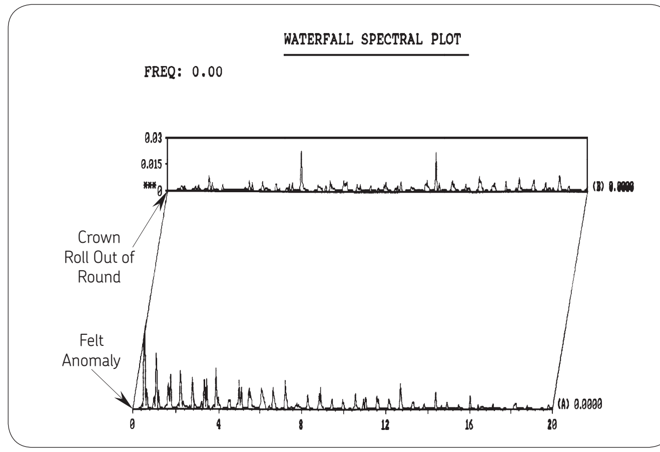


Fig. 5. Waterfall spectral plot – The filtered, enveloped time domain signal.

How the measurements were made

The SKF recommended press section monitoring solution features an SKF Multilog (Local Monitoring Unit) LMU allowing for up to 32 sensor inputs, eight tach triggers, and eight logic inputs. The vibration sensors are generally accelerometers, although the LMU can accommodate velocity and displacement sensors as well. Signals from other sensors, such as current probes, temperature and pressure can also be collected and measured as part of the condition monitoring process. Sensors for acceleration enveloping measurements do not require special high sensitivity or low frequency cutoff, since the higher harmonic signal components are folded back to base band frequencies, enhancing their values as a result of the enveloping process. The accelerometer is often installed with a special adhesive, near the bearing load zone or the press nip zone. The preferred attachment method, however, is a threaded hole to accept the accelerometer stud, resulting in the most reliable means to optimize band width and transmissibility. In the case study described, the accelerometer was attached to the granite roll bearing housing.

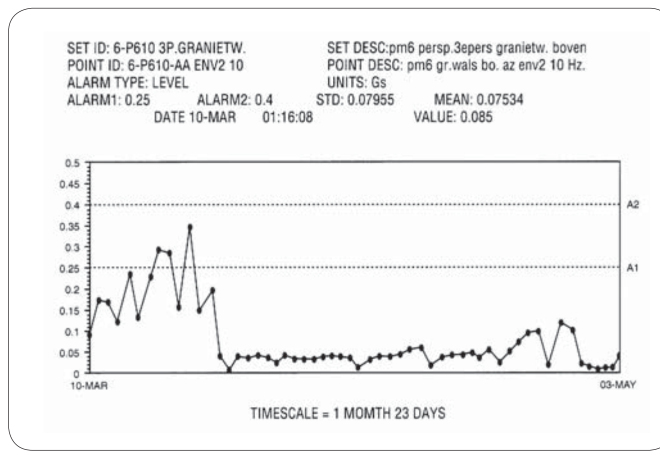


Fig. 6. Overall value versus time trend – Long term trend after corrective maintenance.

The LMU measurement schedule and route was downloaded from the host computer to measure in acceleration envelope mode with a bandpass filter selection of 5 to 100 Hz, fmax of 200 Hz, with 6 400 line resolution. In many instances, operators have found it preferable to measure the same sensor point with several filter selections, ensuring early detection of press section malfunctions. A rule of thumb is to select the high pass corner frequency to be at least ten times the running speed of the machine being observed.

A data collection schedule was set up to transfer the current spectral data to the host computer for spectrum viewing and trend analysis. When the computer is used in the analysis mode, the LMU continues to monitor and store current spectrum and alarm data. On-line monitoring of spectrum, time and trend plots were also viewed in the analyzer mode for the most current condition update.

Summary

In this case study, SKF undertook the responsibility for the system design, component selection, hardware installation, training and overall supervision. An innovative cabling method was designed to allow for the easy removal of sensor and cable assembly during the frequent felt and roll replacement intervals. As the system turnkey vendor, the local SKF service office was able to apply many years of knowledgeable expertise accumulated from bearing support services, as well as from numerous installations of machinery monitoring and protection systems.

The SKF Multilog system performs all measurements, stores current vibration and alarm data. The use of periodic gating allows data collection to be focused on a particular machine condition, thereby reducing the amount of data to be analyzed. Communication to the LMU is via an RS-485 communication line that permits up to 64 LMUs to network with the host computer. Each LMU independently multiplexes all sensor channels, converts analog signals to FFT spectra and compares them to the selected alarm criteria. The host polls each LMU for alarm flags and current data. When on-line analysis is required, the most current data of the selected point is updated to a split screen view of spectrum magnitude, timebase and overall trend. Another on-line feature simultaneously displays a "live" bar graph of current channel status.

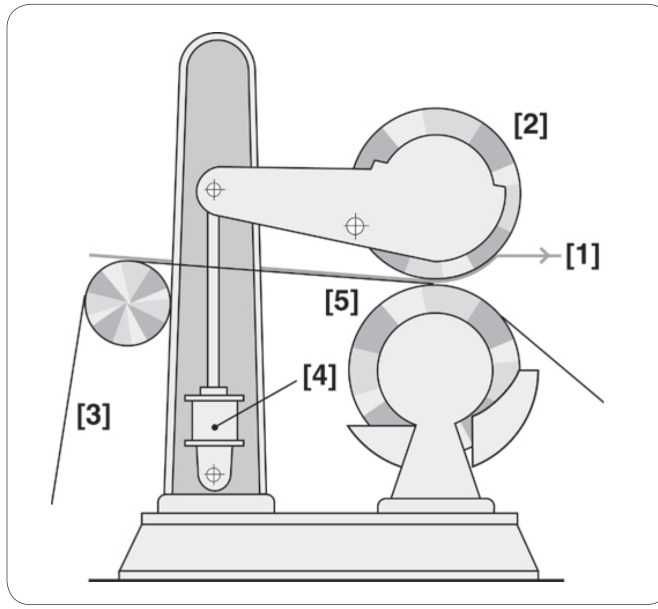


Fig. 7. [1] Paper web, [2] Granite roll, [3] Felt, [4] Pneumatic piston, [5] Rubber-covered bottom roll.

Because of the demonstrated increase in paper quality and output experienced at this papermill, the press section monitoring system described has been recently enhanced with several additional LMUs to also monitor the dryer section of the paper machine as well.

SKF produces a compete line of fully integrated machinery condition monitoring sensors, instrumentation software, services and training to help SKF customers improve process productivity by achieving trouble-free operation.

Understanding acceleration enveloping

Acceleration enveloping techniques employ demodulation circuits that are very useful for analyzing impulse data. There are many practical machinery problems that produce impulse forces, such as those usually related to a component fault. Examples are when a bearing rolling element contacts a ring defect, or press roll flat spot rotates through a nip, or a felt joint discontinuity, or worn gear mesh. Very often these response signals are very small when compared to 1x, 2x, 3x amplitude responses to imbalance and misalignment, for example. Low and high frequency machinery noise further obscures these very important fault indicators.

Using normal FFT analysis and employing acceleration or acceleration or integrated to velocity, early signs of an incipient failure of a bearing, roll, felt or gear is very difficult to detect. Acceleration enveloping measurements, however, can isolate and enhance these weak impulses. If a vibration impulse signal appears in the spectrum analysis as a repetitive harmonic series, then the type of fault is recognized by the repetition frequency (inner ring, outer ring, ball pass, roll rotation, gear tooth) and quantified by its overall value. If the spectrum does not contain identifiable vibration peaks, then the fault is usually either too small or does not exist.

The block diagram of the normal measurement is shown in **fig. 8**. Even though a defect bearing element roll over, roll flat spot or felt anomaly is present as a small pulse, traditional vibration analysis is generally too insensitive to detect the early defect stages. The same signal, when measured through the acceleration enveloping technique (→ **fig. 9**), will be identifiable provided the impulse response signal exceeds the instrument threshold.

The bandpass filter strips the impulse train from high amplitude vibration by attenuating both low and high frequency signals and amplifying only the bandpass amplitudes. The envelope demodulator enhances and reformats the impulse train. If the signal is not impulsive, then the acceleration envelope spectrum will not show the defect repetition rate.

To draw another perspective on the acceleration enveloping measurement technique, consider that the filter passes only the harmonic series amplitudes of the impulse, while the enveloper approximately squares the filtered signal. The squaring process produces sum and difference components. All the lower difference components represent a vectorial summation of a base band display. Non-impulsive waveforms will not contain the harmonic series and the output of the enveloping demodulator will not have formatted an impulse waveform.

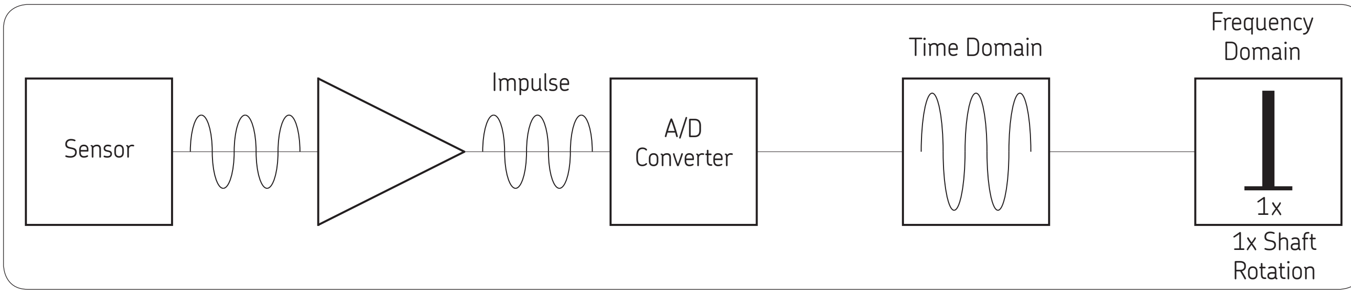


Fig. 8. Block diagram of normal measurement.

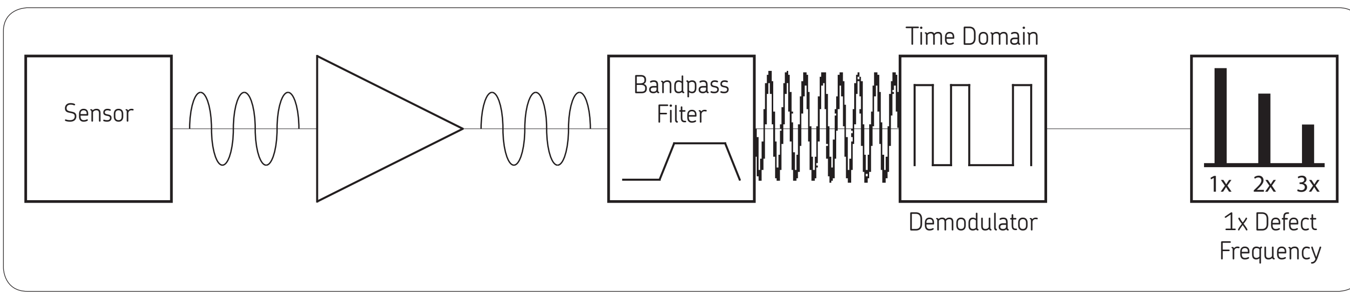


Fig. 9. Acceleration enveloping FFT conversion.

A dramatic simulation of the sensitivity of the enveloping process is illustrated by the following sequence of time and frequency plots. **Fig. 10** is a time domain display of a simulated signal that combined a 0.01 g, 3 ms pulse with a 24 g, 0.5 Hz sine wave. This small impulse compared to the large sine signal is said to be 64 dB down. It is not discernible in the time domain plot. The normal FFT spectrum (**→ fig. 11**) only shows the 0.5 Hz, 24 g signal and nothing related to the impulse.

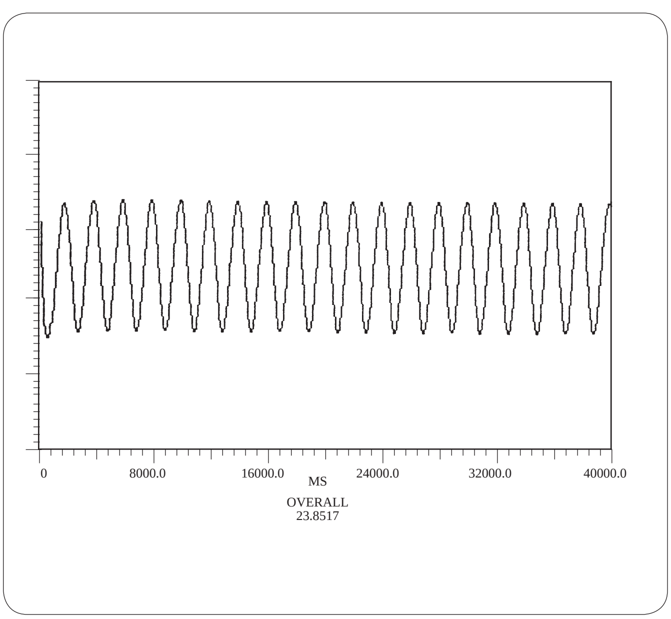


Fig. 10. 0.5 Hz 0.01 g summed with 0.5 Hz signal 3 ms pulse.

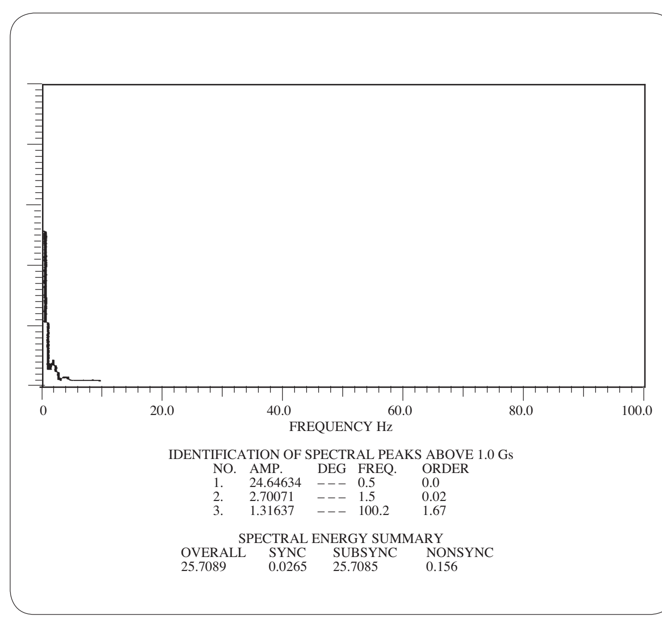


Fig. 11. Normal spectrum.

Fig. 12 shows the demodulated signal with only the enhanced impulse present. **Fig. 13** is the FFT spectrum of the output of the enveloper, illustrating the impulse signal repetitive peaks.

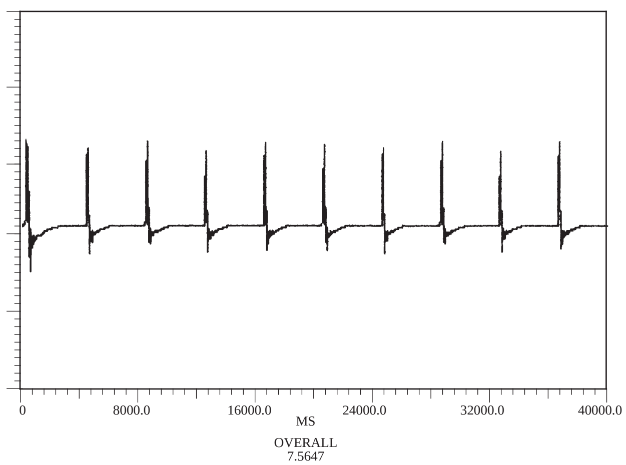
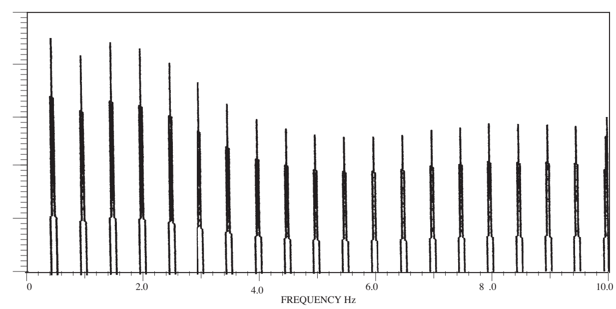


Fig. 12. Enveloped time domain.



IDENTIFICATION OF SPECTRAL PEAKS ABOVE 1.0 Gs

NO.	AMP.	DEG	FREQ.	ORDER	NO.	AMP.	DEG	FREQ.	ORDER
1.	0.04417	– – –	0.5	0.0	9.	0.02697	– – –	4.5	0.07
2.	0.04071	– – –	1.0	0.01	10.	0.02577	– – –	5.0	0.08
3.	0.04301	– – –	1.5	0.02	11.	0.02647	– – –	7.0	0.11
4.	0.04189	– – –	2.0	0.03	12.	0.02699	– – –	7.5	0.12
5.	0.0394	– – –	2.5	0.04	13.	0.02759	– – –	8.0	0.13
6.	0.03545	– – –	3.0	0.05	14.	0.02754	– – –	8.5	0.14
7.	0.03168	– – –	3.5	0.05	15.	0.02729	– – –	9.0	0.15
8.	0.02865	– – –	4.0	0.06	16.	0.02706	– – –	9.5	0.15

SPECTRAL ENERGY SUMMARY

OVERALL	SYNC	SUBSYNC	NONSYNC
0.142	0	0.142	0

Fig. 13. Enveloped spectrum.

Please contact:

SKF USA Inc.
Condition Monitoring Center – San Diego
5271 Viewridge Court · San Diego, California 92123 USA
Tel: +1 858-496-3400 · Fax: +1 858 496-3531

Web: www.skf.com/cm

PUB CM5005 EN · February 2012