TECHNICAL NOTE

VIBRATION MONITORING OF ROLLING ELEMENT BEARINGS

There are many various **signal processing techniques** implemented for the **vibration diagnosis of bearings** on rotating machines. They can be sorted into three main categories:

- **Frequency methods**: Narrow-band spectral analysis (FFT), envelope analysis (amplitude demodulation), cepstrum analysis.

- **Time methods or statistical methods**: **RMS** value (*overall level* over a given frequency band, *usually for acceleration and in high frequencies for bearings: > 1 kHz*), peak value, peak factor, **kurtosis** and manufacturer's acceptance tests: defect factor **DEF**, **SEE** technology, **Gse**, etc.

- **Filtering methods** applied to time signals: essentially high pass and band pass, denoising by spectral subtraction of all periodic components.

Frequency processing consists in detecting the presence of **periodicities** due to repeated shocks generated by the possible marking of an inner or outer raceway or by the scaling of rolling elements.

Among the aforementioned techniques, **envelope analysis** is the most advanced tool.

Warning!

❍ Envelope analysis can lead to gross diagnosis errors, since the presence of a set of harmonic lines does not necessarily reflect the occurrence of periodic shocks.

❍ It is rather complex to implement this technique since it requires to know beforehand the frequency domain of interest for demodulation (resonance area). *Restricted* to the search for bearing defects and/or clearances, it is usually associated with:

- ▫ narrow-band analysis (FFT) allowing for the dynamic characterisation of the line of shafting.
- ▫ statistical processing, such as **Kurtosis**.

Cepstral analysis is used to easily extract and quantify sets of harmonic lines observed on a power spectrum: *the richer the shock spectrum (as for the number of components and their emergence with respect to background noise), the higher the amplitude on the cepstrum for the fundamental line of this shock spectrum.*

Another advantage is the relative lack of sensitivity to load variations and to modifications of transmission paths between excitation source (*bearing*) and transducer.

Kurtosis

Kurtosis is a statistical indicator used to characterise the pulse character of a signal. It is a dimensionless parameter characterising the flattening of the signal probability density (see Fig. 1).
It corresponds to the 4th-order moment:

$$Kurt = \frac{1}{N}\sum_{i=}^{N}\left(\frac{x(i)-\mu}{\sigma}\right)^4$$

▫μ *represents the average (1st-order moment)*
▫σ *represents the standard deviation (2nd-order moment)*
▫ *in case of a centred signal (zero average), the standard deviation tends to the RMS value*

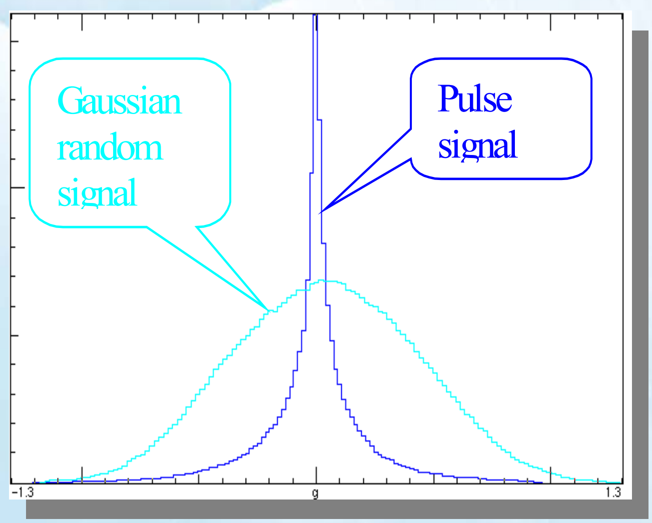

Figure 1: Probability density

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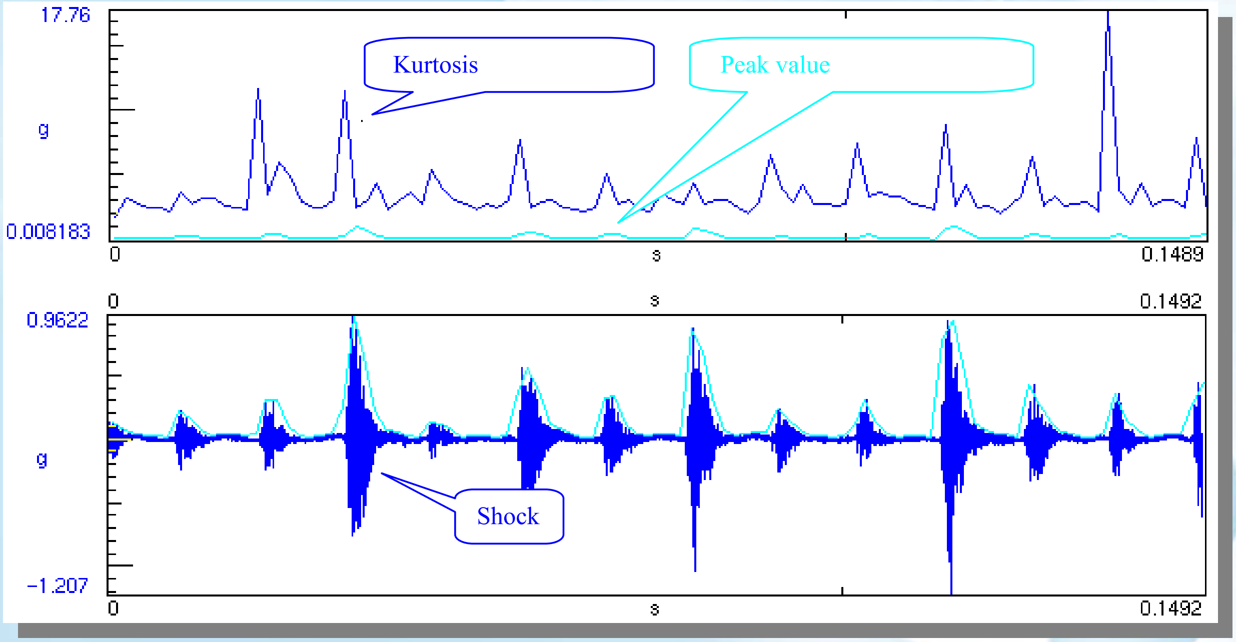


Figure 2: Calculation of Kurtosis in the sliding window of a pulse signal

Advantages

❍ Kurtosis can be assimilated with a shape factor, the value of which does not depend on the signal amplitude:

▫ *sine signal:*	Kurt = 1.5
▫ *square signal:*	Kurt = 1
▫ *Gaussian signal:*	Kurt = 3
▫ *pulse signal:*	K > 3

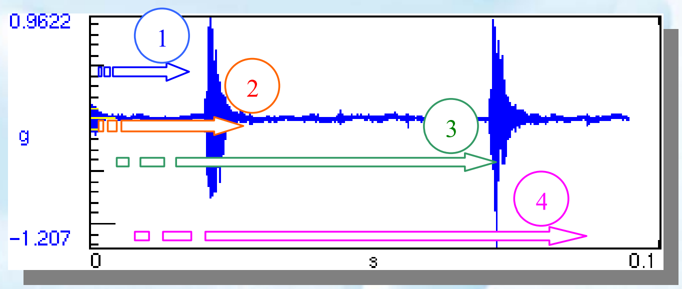
❍ Figure 2 allows to evidence the great sensitivity to shocks exhibited by Kurtosis. It is particularly suited to the monitoring of bearings of low speed rotating shafts, where frequency-based techniques are limited. Kurtosis is also widely used to detect non periodic shocks.

❍ In practice, Kurtosis is often calculated after filtering. It can reach values greater than 100, especially when the selected frequency band coincides with a structure resonance. Also, it is often associated with envelope analysis to determine the area to demodulate.

Drawbacks

❍ Like for the **peak factor**, there is one major drawback: it decreases as defects become very important. It is then highly recommended to monitor the RMS value of the signal at the same time.

❍ It can be erroneous. Let's consider, for instance, a random signal (Fig. 3). Under the influence of a strong impulse, its value is going to increase suddenly. After the impulse and in the event there is no further impulse, the signal



amplitude keeps on progressively increasing until the measurement is terminated.

Figure 3: Kurtosis variations

duration	*RMS values*	*KURT*
1	15 mg	2.3
2	120 mg	24
3	74 mg	62
4	102 mg	39

Tools

For many years, frequency methods have been available in most measuring systems devoted to the **predictive maintenance** of rotating machines and specifically to the diagnosis of bearing defects.
Unfortunately, it is not really the case for the two other categories of processing, that are however useful for diagnosis and easy to implement. Although all systems can provide overall vibration levels in different frequency bands, very few allow to properly view signals in the time domain, filter them and finally calculate Kurtosis.

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