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Application Note

Primer for Cepstrum analysis – a powerful tool for simpler diagnosis of REB and gear vibrations

A post-process Cepstrum analysis calculation can be performed on any standard FFT spectrum or envelope spectrum, and has a special place in the simplification of the analysis of vibrations created by machines such as gearboxes – which are mostly extremely difficult to analyse – or machines equipped with rolling-element bearings. The principle is simple when understood and the results are clear and definitive and normally leave the analyst in no doubt as to the source of the machine fault.

Cepstrum analysis is the name given to a calculation technique involving a function that can be described as a "spectrum of a logarithmic spectrum" or a backward transform to the time domain. Because it is basically a "spectrum of a spectrum" the name was derived by reversing part of the word spectrum, and a number of terms are commonly used for the parameters of a Cepstrum, namely

- Quefrency instead of frequency
- Rahmonics instead of harmonics, and
- Gamnitude instead of magnitude.

This type of paraphrasing led to the practice of using Cepstra being called

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What does a Cepstrum do?

The main application of a Cepstrum is to serve as a post-process calculation to determine any harmonic structure and the existence of sideband families in a spectrum, which both arise as a result of regular impact vibrations in machines equipped with rolling-element bearings or gears.

It is well known that the position at which a spectrum measurement is taken on an object will determine what the spectrum looks like. This happens because each different location on a machine has a different mobility. The entire object experiences all the vibration forces which exist in it but depending upon where the spectrum is measured it can have a different appearance.

This principle is shown in the figure below.

What are the advantages of a Cepstrum?

<u>A) Separation of the effects of the source and the transmission path</u>

The mobility of a measurement point has a direct effect on the appearance of the spectrum measured at that point. This effect is illustrated in the figure below.

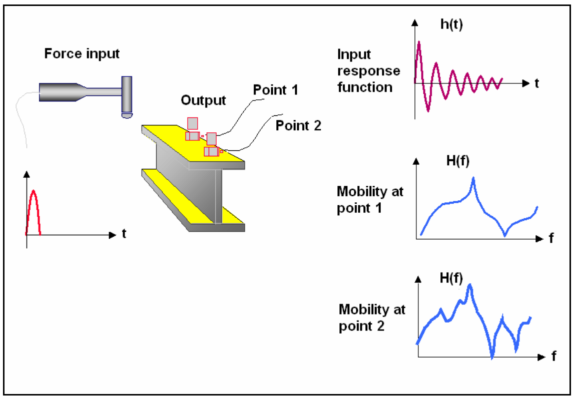

Fig. 1: The effect of different mobility on the spectrum appearance

However in the case of a Cepstrum measurement, the measurement location has a minimal effect since the Cepstrum looks for the presence of evenly-spaced components in the spectrum – or the properties of the spectrum – and not at the spectrum as a whole.

In a practical example below it can be seen how the transmission path and the source have the tendency to separate in the Cepstrum.

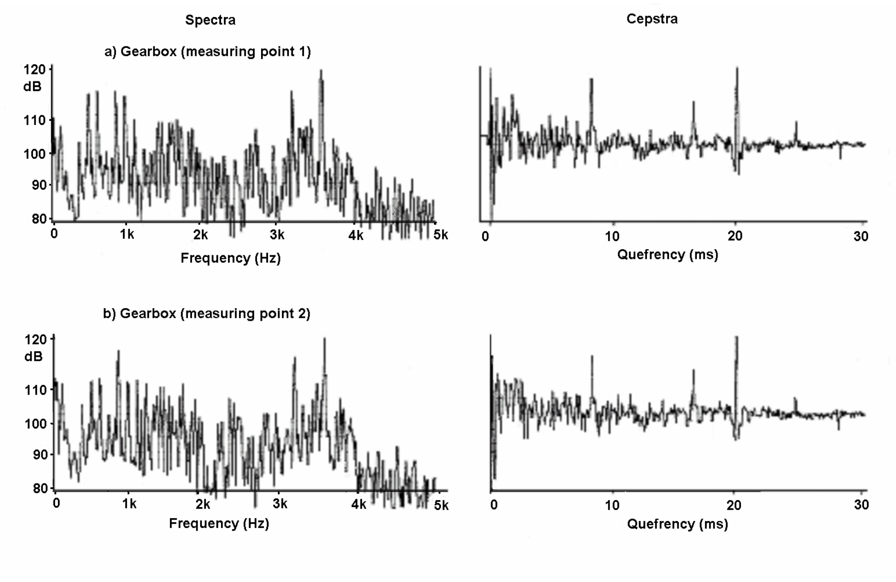

Fig. 2: Separation of source and transmission paths

The two FFT spectra above are very similar in appearance, with some exceptions, e.g. in the area between 2 kHz and 3 kHz, where peaks and valleys alternate. In addition the amplitudes of individual peaks are also different.

However in the Cepstra all the important peaks that represent harmonic families are present in both cases and the amplitudes of the peaks are also the same. Only at the unimportant lower quefrencies are the two Cepstra different.

<u>B) Detection of periodicity</u>

One of the first properties that we automatically – almost subconsciously - look for in a spectrum is the appearance of harmonic relationships simply because they are normally easy to identify. However, as stated before, in a complex spectrum it is often almost impossible to see such relationships.

Because the Cepstrum looks specifically for these relationships it offers assistance in these cases. Therefore Cepstrum is useful for identifying faults from damaged rolling-element bearings, gears and blades.

The figures below illustrate this unique feature of a Cepstrum, in that although the presence of regular events can sometimes be identified in a standard FFT spectrum by the even spacing of the components, in a complex spectrum this is easier to identify by making a Cepstrum calculation and then examining it for the existence of just a single line that identifies the harmonic or sideband family.

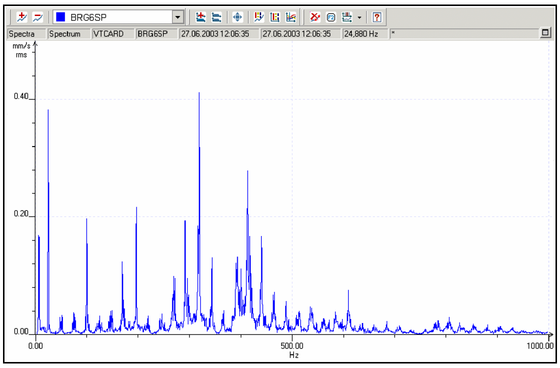

Fig. 3: Standard FFT spectrum showing apparent periodicity

The figure above shows a spectrum from a machine with a faulty rolling-element bearing, with apparent harmonic activity. The Cepstrum calculated and shown in figure 4 below provides absolute confirmation that the activity is indeed harmonic, as indicated by the single dominant line at a quefrency of approx. 40 ms.

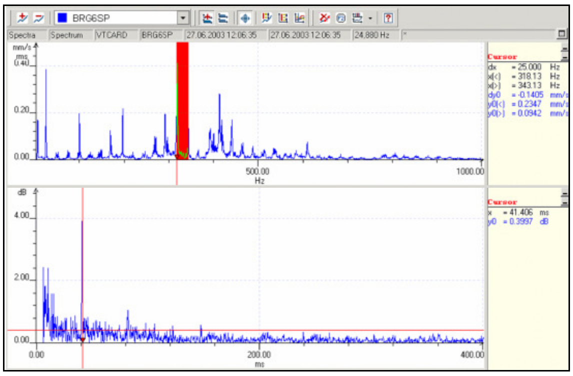

Fig. 4: The original FFT spectrum (top) and the corresponding Cepstrum (bottom)

Even in the case of clearly different FFT spectra, the spectra are interrogated by the Cepstrum calculation only for the presence of harmonic activity.

In figure 5 two different time signals and their respective FFT spectra are shown. The upper time signal has its maximum amplitude at maximum frequency while the lower time signal is the opposite, i.e. maximum amplitude at minimum frequency. The effect of this can be clearly seen in the corresponding standard FFT spectra in which there is a clear fundamental difference between them.

However the Cepstra show that the harmonic activity in each of the two signals is the same and confirms that the Cepstrum is sensitive only to the presence of sideband/harmonic activity and not to phase differences.

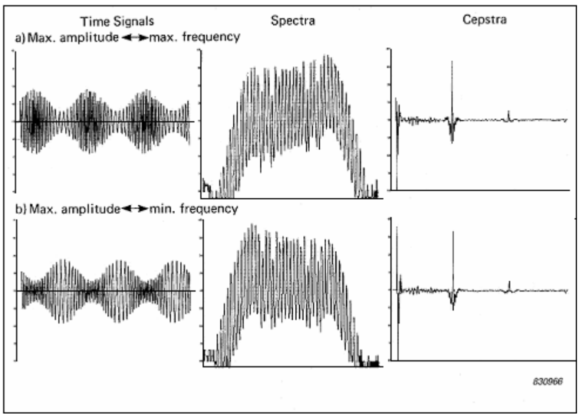

Fig. 5: Cepstrum focuses on repeat events

Summary

The Cepstrum can therefore be said to be extremely advantageous for the following two tasks in vibration monitoring and analysis:

For fault detection

a) It is a sensitive measure of the growth of harmonic/sideband families.

b) The data is reduced to a single line per family.

c) It is insensitive to

- Measurement point location
- Phase combination, amplitude and frequency
- Loading

For fault diagnosis

a) It is an accurate measure of spacing

b) Can be calculated from any section of a spectrum

c) Can be used for separation of different families

d) It is sensitive to tooth and blade differences but not uniform wear

With the appropriate application Cepstrum can make the job of the diagnostic technician easier and more certain when it comes to a correct diagnosis of a fault that may require a shutdown of a machine.

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