Assessing bearing condition using CF+

Fluke, which is represented in South Africa by Comtest, presents a white paper that explains the use of a newly developed Crest Factor Plus (CF+) Fluke 805 vibration meter. This removes the need for trending associated with using the traditional Crest Factor analysis.

Bearings ensure smooth machine rotation with minimum friction, which saves energy, extends machine life and, on production lines, enhances final product quality. This makes them a critical machine part.

Even when maintained properly, bearings will sooner or later wear out. So, the question is not whether a bearing is worn out but rather when it will be. Knowing when machine bearings need to be replaced enables operators to plan shutdowns, schedule personnel and order bearings more efficiently.

Vibration testing

Vibration testing is a proven technique for predicting bearing condition. The vibration sensors and measuring equipment are so sensitive that they detect even slight changes in bearing condition. Broadly speaking, vibration testing can be divided into two groups: testing based on frequency analysis and testing based on 'overall values'.

Frequency analysis not only makes the bearing condition visible, but also shows exactly what is wrong with the bearing; and what type of defect is present in which part of the bearing. Overall values like those shown on the Fluke 805 vibration meter indicate that something is wrong, without giving details about the nature of the defect or which bearing part is affected. This technique has the advantage of being fast and relatively simple with straightforward results, and adds the possibility of automating bearing condition assessment.

Bearing wear

Even when perfectly installed and regularly maintained, bearings will develop defects as a result of fatigue. The main reason for this fatigue is the load on both the rolling elements (balls and rollers) and raceways, which vary as the shaft rotates.

The rolling elements and raceways are compressed in the load zone (Figure 1) and expand to their original form when leaving it. This alternating stress causes microscopic cracks under the surface, which later emerge on the surface as cracks, spalls and finally permanent brinelling damage.

Other causes of defects are poor lubrication, contamination, overload from over speed and high load, and shaft voltages. Shaft voltages are caused by buildup of electric charges at the motor shaft, with the discharge current going through the bearing to the ground. This causes pits in the rolling elements and fluted raceway surfaces (Figure 2).

Bearing condition assessment

Each time a rolling element passes a crack or spall it impacts on the bearing structure, which will start to resonate or ring (Figure 3B). The same kind of ringing is heard when a clapper hits a bell. The resonances in the bearing structure have a frequency of between 4.0 kHz and 20 kHz.

The peak vibration value is an excellent measure of bearing condition - the more severe the defects, the higher the impact and the higher the response. However, to use this parameter, the ringing from the bearing must be separated out from the much stronger vibrations that come from the machine. These stronger vibrations are caused by unbalance, misalignment or looseness. The bearing vibrations are therefore filtered to frequencies between 4.0 kHz to 20 kHz by a bandpass filter. The machine vibrations are filtered to frequencies between 10 Hz to 1.0 kHz and are measured to obtain results that can be compared to those in the Mechanical Vibration Standard, ISO 10816.

The measurement techniques used so far (filtering and peak detection) are relatively simple, which is a great advantage since it keeps measurement equipment affordable. The disadvantage however becomes clear when the measurements are conducted at different rotational speeds - as the level of impact depends on the speed. So, a much better parameter than simply the peak value is the Crest Factor, since the Crest Factor cancels out the influence of speed.

The Crest Factor is defined as the peak value divided by the root mean square, which represents the energy content of the vibration signal. The higher the speed, the higher the RMS and peak values, so the ratio remains the same. If the bearing condition worsens, the Crest Factor will rise (Figure 4).

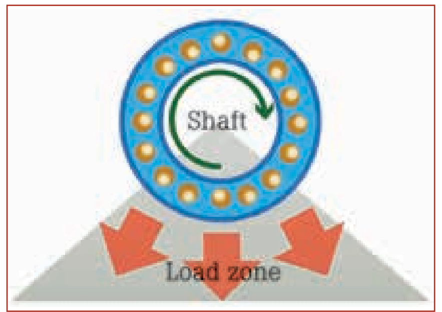

Figure 1: Raceway and bearings compress and expand during every revolution.

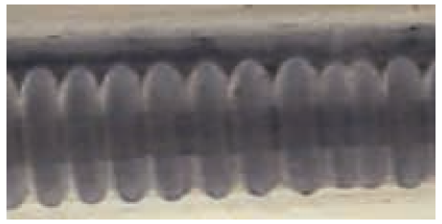

Figure 2: A fluted bearing raceway.

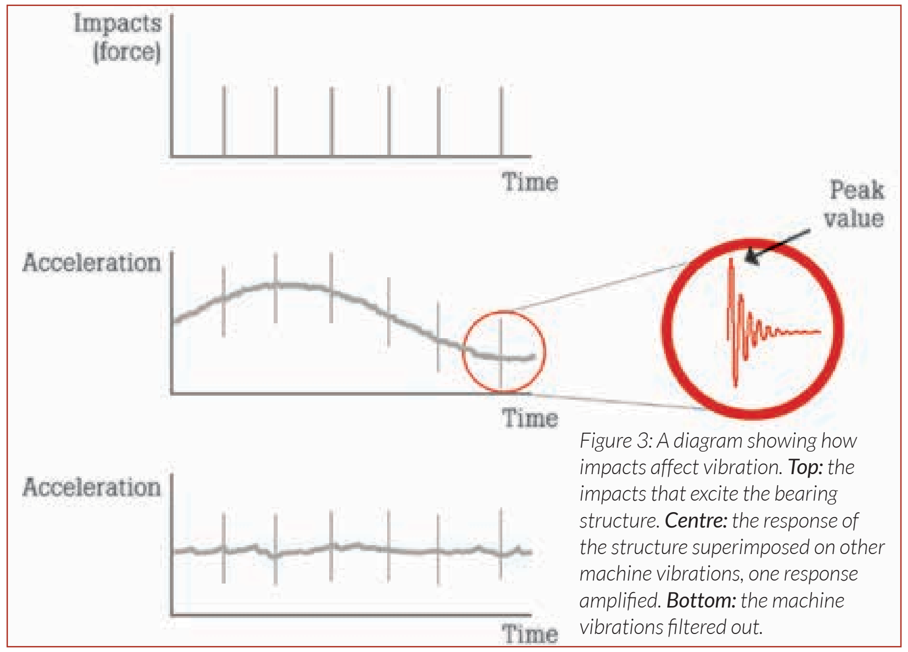

*Figure 3: A diagram showing how impacts affect vibration. **Top:** the impacts that excite the bearing structure. **Centre:** the response of the structure superimposed on other machine vibrations, one response amplified. **Bottom:** the machine vibrations filtered out.*

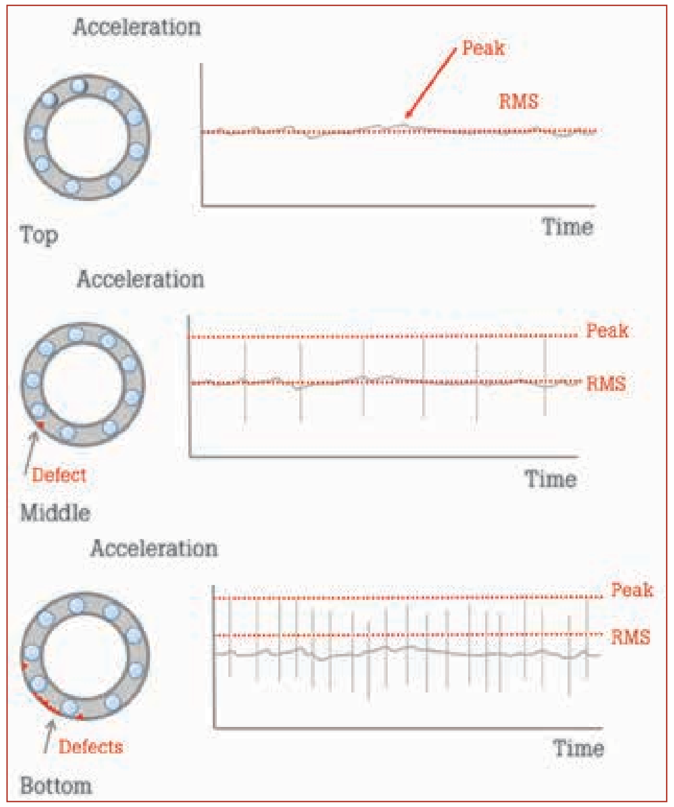

Figure 4: The peak and RMS values as a bearing deteriorates (top to bottom).

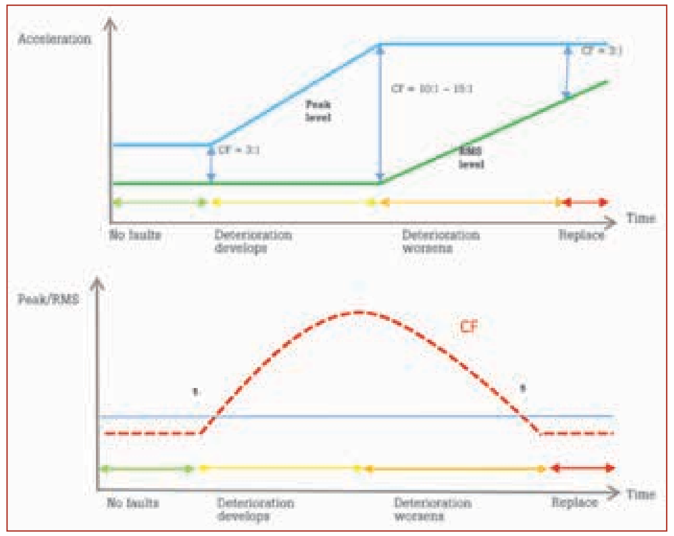

Figure 5: A summary of the Crest Factor behaviour as bearing wear increases, top: peak and RMS values with respect to bearing condition and, bottom: associated variation in the Crest Factor.

The somewhat bumpy line on Figure 4 shows the bearing noise caused by default imperfections in the bearing parts. These arise mainly from the surface roughness of raceways and rolling elements and the waviness of the raceways. Poor lubrication will strengthen these effects. Peak and RMS values are very close together with a Crest Factor with typical values from 1 to 3.

Figure 4 shows a defect that causes peaks. The peaks are so brief in time that the energy content tends to zero, so the RMS level remains the same as before. The Crest Factor therefore increases. In Figure 4, the number and severity of defects grows and the deterioration process gains momentum due to brinelling particles and debris that in turn cause defects. The number of peaks therefore grows and starts to contribute to the RMS level. In short, the Crest Factor starts to decrease again.

The advantage of Crest Factor is that it is independent of rotational speed. Figure 5 shows the disadvantage of Crest Factor. A Crest Factor of, for example, 5 could mean the bearing is in good condition but it could also mean that it must be replaced at short notice.

The Crest Factor, therefore, only makes sense as a bearing condition parameter when it is trended, in order for the maintenance staff to know the exact bearing condition over time.

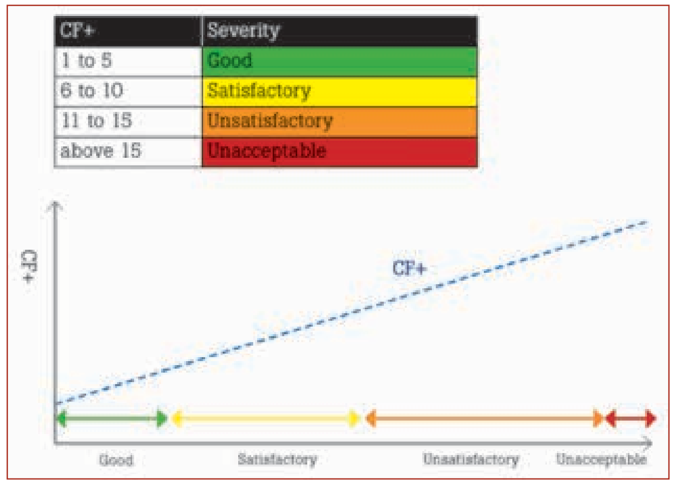

Figure 6: The CF+, which uses c1, c2 and c3 factors chosen so that the decreasing Crest Factor is counteracted by the increasing RMS value, increases linearly as the motor condition progresses from good to unacceptable. (CF+ = c1×RMS+c2×Peak+c3×CF).

CF+ and automatic bearing assessment

The parameter Crest Factor plus (CF+) has been developed to remove the need for trending, and immediately gives the condition of a bearing irrespective of the rotational speed. This parameter is similar to Crest Factor but is corrected to account for the increased number of peaks so that CF+ always increases as the bearing condition worsens (Figure 6).

Figure 7: The Fluke 805 screen shows bearing condition, overall machine vibration and temperature measured simultaneously.

The formula for CF+ uses c1, c2 and c3 factors chosen so the decreasing Crest Factor is counteracted by the increasing RMS value. Fluke 805 instruments use this factor to automatically assess the bearing condition (Figure 6).

Fluke 805 and Fluke 805 FC

Besides measuring overall machine vibration, both Fluke 805 and Fluke 805 FC (with Fluke Connect) automatically determine CF+ values (Figure 7). They therefore incorporate the advantages of Crest Factors, while eliminating the disadvantages. Like the Crest Factor itself, CF+ can be used for trending, but it also gives a unique, automated assessment of the bearing condition. The parameter is independent of rotational speed and bearing dimensions so this information is not needed to assess the bearing condition. Overall vibration, or the second parameter, is used for comparison to ISO standards and for trending. This parameter is expressed as velocity; an integration of the acceleration signal.

A third parameter, temperature, is also measured simultaneously, which is useful for trending and as a 'second opinion' with respect to the bearing's condition assessment. ❑