Vibration Analysis Definitions

振动分析定义

Mobius institute

33cm.net

Vibration Analysis Definitions 英文链接：

http://www.mobiusinstitute.com/site2/item.asp?LinkID=2001

由于时间仓促，译者水平有限，错误之处还请指正。

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主题：各行各业各种动设备的状态监测与故障分析诊断；设备检维修；实用型之状态监测信号分析与处理；

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目 录

1 Analysis Definitions: Unbalance 不平衡

Symptoms: 1X radial (V & H)

The technical way to describe unbalance is as a condition where "a shaft's geometric centerline and mass centerline do not coincide", or where "the center of mass does not lie on the axis of rotation". In other words, there is a heavy spot somewhere along the shaft.

There are two types of unbalance: static and couple. Normally there is a combination called "dynamic" if the rotor is not narrow compared to its diameter.

We expect to see a high peak in the spectrum at 1X turning speed of the shaft. It is often higher in the horizontal direction compared with the vertical direction due to stiffness.

Waveform: The waveform should be very sinusoidal; if not there may also be misalignment, looseness or other fault condition in addition to unbalance. View in units of velocity if possible.

Phase: Phase is the best indicator. Compare vertical to horizontal phase – there should be a 90° phase shift.

See also static and couple unbalance, and unbalance for vertical machines and overhung machines.

特征：1X 径向（V&H）

不平衡定义：转轴的几何中心线和质量中心线不重合时的一种状态。或质量中心线不在旋转轴线上。换句话说，转轴上有个重点。

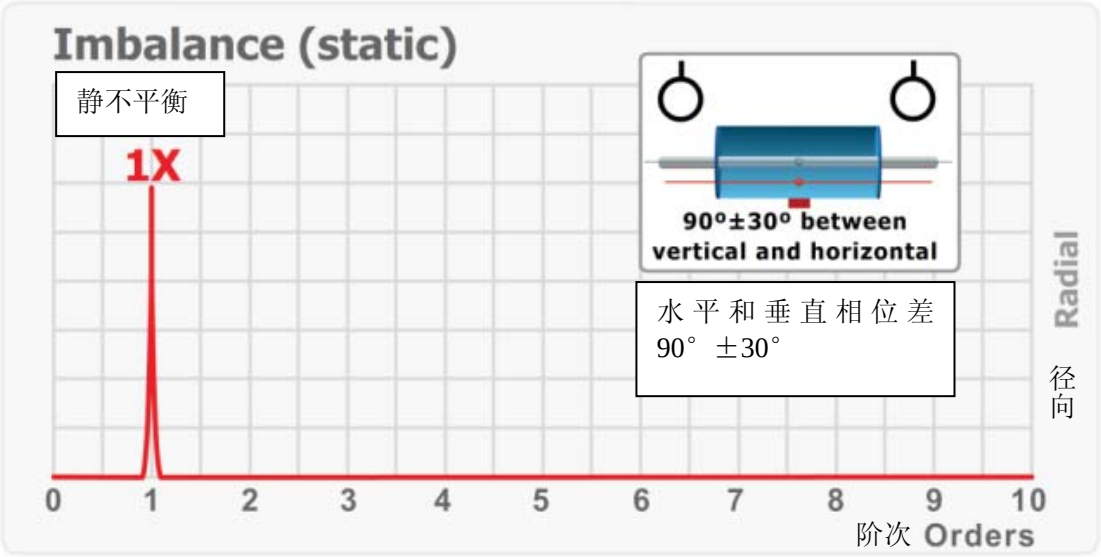
两种类型的不平衡：静不平衡和力偶不平衡。如果转子的跨度相比较直径不是太窄的话，通常是两种类型的组合，即动不平衡。

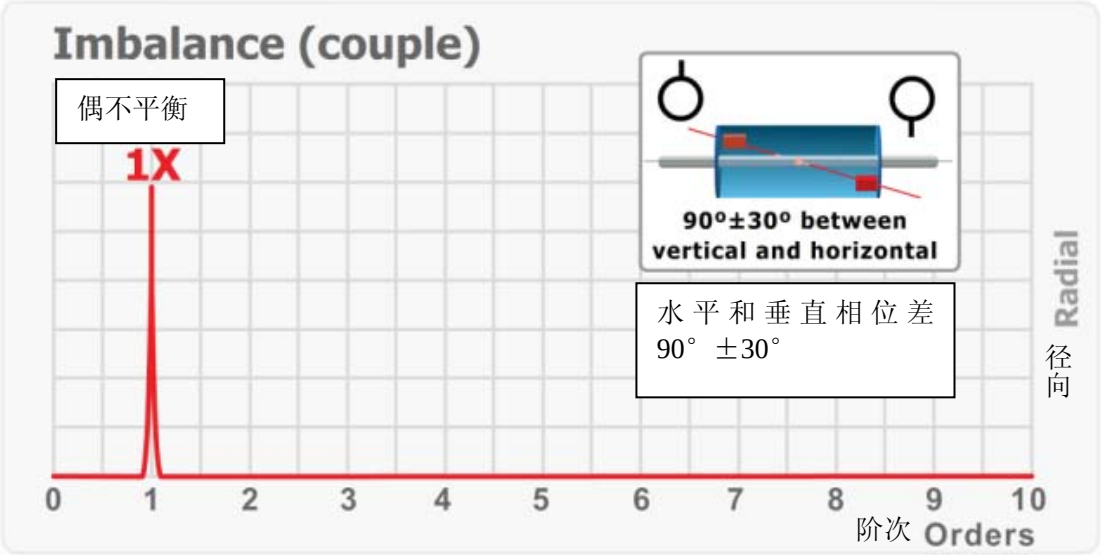
我们会在频谱中看到 1X 转频幅值较高。由于刚度不同，水平方向振值较垂直方向大。

时域波形：时域波形应该是正旋波；如果不是，可能是不对中，松动或其它故障（除了不平衡）。尽量采用速度单位。

相位：相位是最好的指示。同一轴承位置的垂直和水平方向间相位差应该是 90°。

另请参阅静和偶不平衡，立式和悬臂设备不平衡。





1.1 Unbalance: Static imbalance 静不平衡

Symptoms: 1X radial (V & H) 特征：1X 径向（V&H）

Expect to see a large peak in the spectrum at the shaft turning speed (1X) in the vertical and horizontal axis. Axial 1X vibration will be low.

我们会在频谱中看到水平和垂直方向的 1X 转频幅值较高，轴向 1X 幅值较低。

The simplest type of unbalance is equivalent to a heavy spot at a single point in the rotor. This is called a static unbalance because it will be present even if the rotor is not turning

最简单的不平衡相当于转子的重点在某个单点上。由于转子停止时也会表现出来，故叫静不平衡。

- if placed in frictionless bearings the rotor will turn so the heavy spot is at the lowest position. Static unbalance can be corrected with a single-plane balance.

如果转子放在无摩擦轴承上，会自动旋转，重点会在最低的位置。静不平衡采用单面平衡校正。

Static unbalance results in 1X forces on both bearings of the rotor, and the forces on both bearings are always in the same direction. The vibration signals from them are "in phase" with each other.

静不平衡会在转子两侧轴承产生 1X 力，两侧轴承的力方向总是一致的，所以两侧轴承同向振动信号是同相的也是一致的。

Spectrum: High 1X in the radial directions. Low in the axial direction.

频谱：径向 1X 幅值较高，轴向 1X 较低

Waveform: The waveform will be very sinusoidal when viewed in units of velocity. If it is not sinusoidal then there may (also) be misalignment, cocked bearing, a bent shaft or some other fault condition.

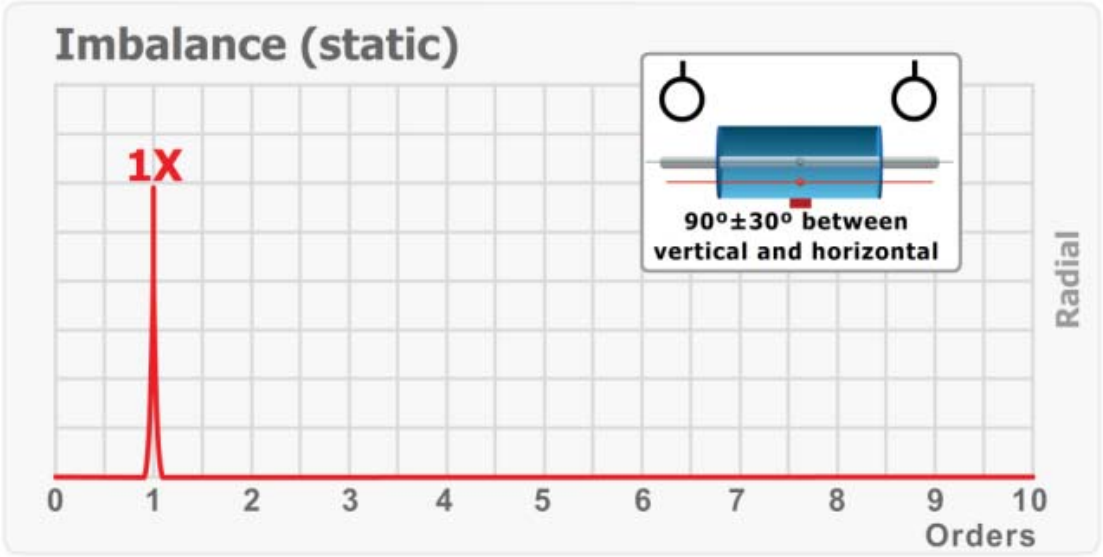
时域波形：采用速度单位时，正旋波。如果不是，可能是不对中，翘曲轴承，轴弯或其它故障。

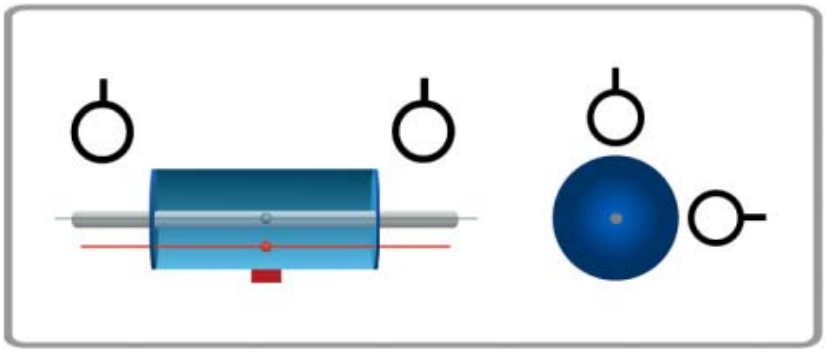
Amplitude: Compare vertical to horizontal vibration on a horizontal machine. If horizontal >2X vertical amplitude then suspect foundation looseness or resonance.

幅值：对于卧式设备，比较垂直和水平方向上的振值。如果水平>2 倍的垂直方向，那么怀疑基础松动或共振。

Phase: Look for 90° phase shift between vertical and horizontal. For pure static unbalance, phase at bearings at either end of the rotor will be in-phase.

相位：同一轴承位置的垂直和水平相位差 90°。对于纯静不平衡，两侧轴承同一方向的相位一致。





1.2 Unbalance: Couple imbalance 力偶不平衡

Symptoms: 1X radial (V & H) 特征：1X 径向（V&H）

Expect to see a large peak in the spectrum at the shaft turning speed (1X) in vertical and horizontal axis. Axial 1X vibration will be low.

A rotor with couple unbalance may be statically balanced (it may seem to be perfectly balanced if placed in frictionless bearings), but when rotated, it will produce

我们会在频谱中看到水平和垂直方向的 1X 转频幅值较高，轴向 1X 幅值较低。

力偶不平衡的转子可能静态时是平衡的（如果放在无摩擦轴承上，看起来平衡状态完美），但是当转子旋转时，它会在两侧轴承产生方向相反的离心力。

centrifugal forces on the bearings, and they will be of opposite phase. > A two-plane balance is required to correct couple unbalance.

力偶不平衡需要采用双面平衡校正。

Spectrum: High 1X in the radial directions. Low in the axial direction.

频谱：径向 1X 幅值较高，轴向 1X 较低

Waveform: The waveform will be very sinusoidal when viewed in velocity. If it is not sinusoidal then there may (also) be misalignment, cocked bearing or some other fault condition.

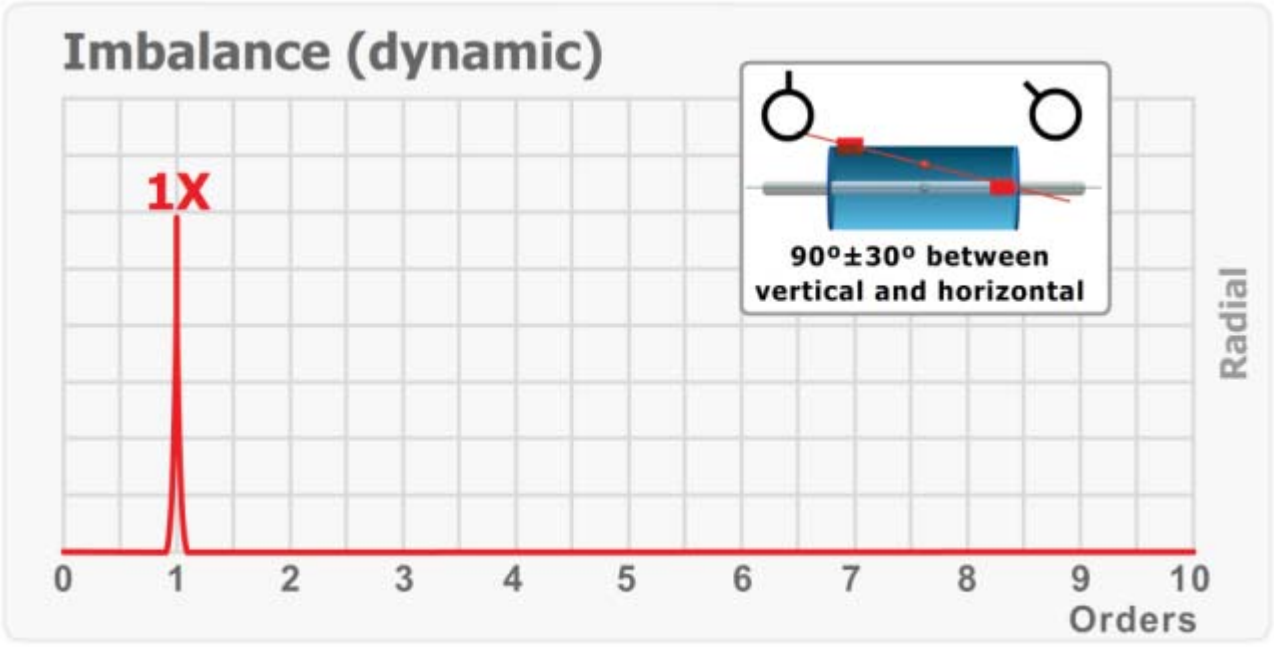
时域波形：采用速度单位时，正旋波。如果不是，可能是不对中，翘曲轴承，轴弯或其它故障。

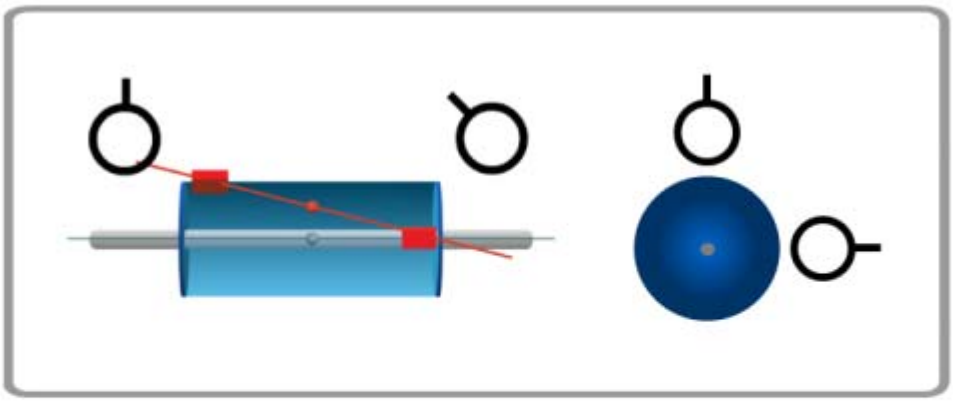
Amplitude: Compare vertical to horizontal vibration on a horizontal machine. If horizontal >2X vertical amplitude then suspect looseness or resonance.

幅值：对于卧式设备，比较垂直和水平方向上的振值。如果水平>2 倍的垂直方向，那么怀疑基础松动或共振。

Phase: Look for 90° phase shift between vertical and horizontal. For pure couple unbalance, phase at bearings at either end of the rotor will be 180° out-of-phase.

相位：同一轴承位置的垂直和水平相位差 90°。对于纯力偶不平衡，两侧轴承同一方向的相位差 180°。





1.3 Unbalance: Dynamic unbalance 动不平衡

Symptoms: 1X radial (V & H) 特征：1X 径向（V&H）

Dynamic unbalance is a combination of static and couple unbalance. It normally occurs in rotors that are long compared to

动不平衡是静不平衡和力偶不平衡的组合。常常发生在转子的跨度相比直径较

their diameter. Dynamic unbalance is the most common form of unbalance in these sorts of rotors. A two-plane balance is required to correct dynamic unbalance.

Spectrum: High 1X in the radial directions. Low in the axial direction.

Waveform: The waveform should be very sinusoidal; if not there may also be misalignment, looseness or other fault condition in addition to unbalance. View in units of velocity if possible.

Phase: Phase is the best indicator. Look for 90° phase shift between vertical and horizontal. Phase at bearings at either end of the rotor will be between 30° and 150° out-of-phase.

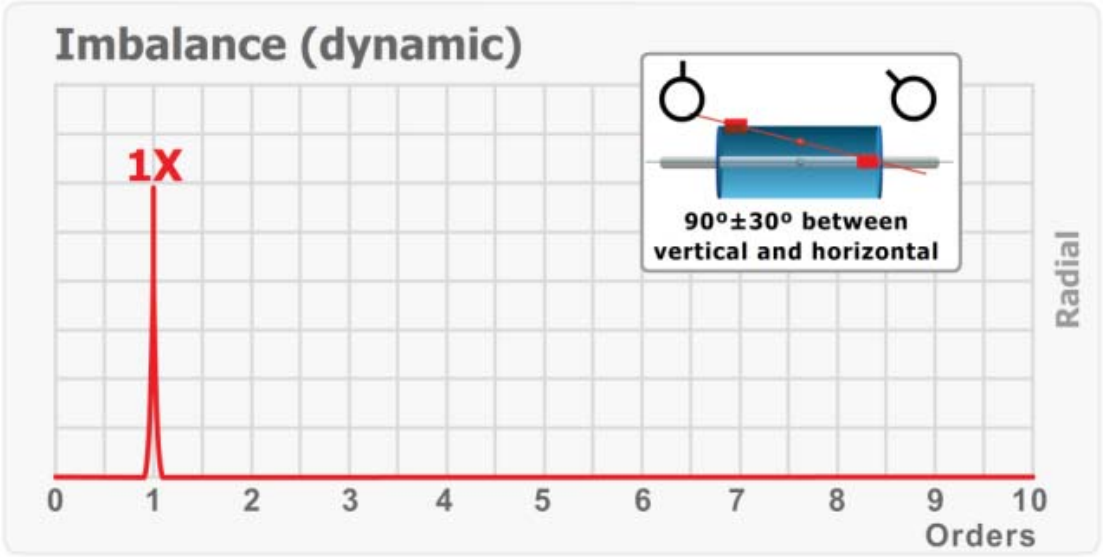
See also static and couple unbalance.

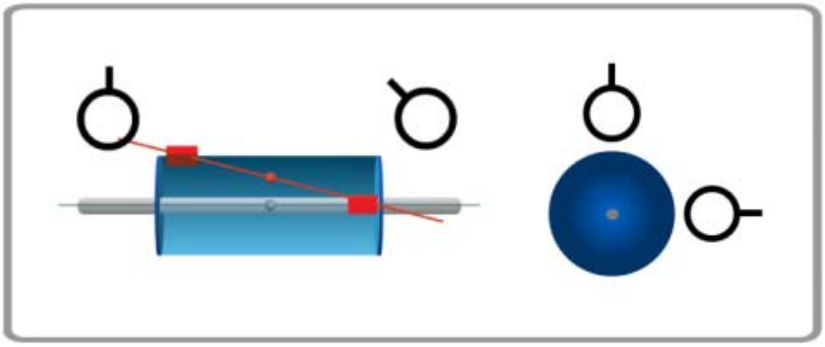
长的情况下，对于这种类型的转子，动不平衡是最常见的。动不平衡需要采用双面平衡校正。

频谱：径向 1X 幅值较高，轴向 1X 较低

时域波形：应该是正旋波。如果不是，可能是不对中，松动，或其它故障（除了不平衡）。尽量采用速度单位。

相位：相位是最好的指示。同一轴承位置的垂直和水平相位差 90°。两侧轴承同一方向的相位差 30° 和 150°。





1.4 Unbalance: Vertical machines 立式设备

Symptoms: 1X radial (horizontal) 特征：1X 径向（水平）

The spectrum will show a high amplitude peak at 1X turning speed when measured in the radial direction (horizontal or tangential).

To distinguish motor unbalance from pump unbalance, it may be necessary to break the coupling and run the motor solo while measuring 1X. If the 1X level is still high, the

在径向方向（水平或切向）测量时，1X 转频幅值较高。

为了区分电机还是泵不平衡，脱开联轴器，单独运行电机进行测量，如果 1X 还是高，那么电机有故障，否则是泵。

problem is the motor; otherwise it is the pump.

Spectrum: High 1X in the radial directions.

Waveform: The waveform will be very sinusoidal when viewed in units of velocity.

Amplitude: Amplitude will be higher where the stiffness is lowest. Typically amplitude will be highest on top of motor, and it will be lowest in the direction of piping.

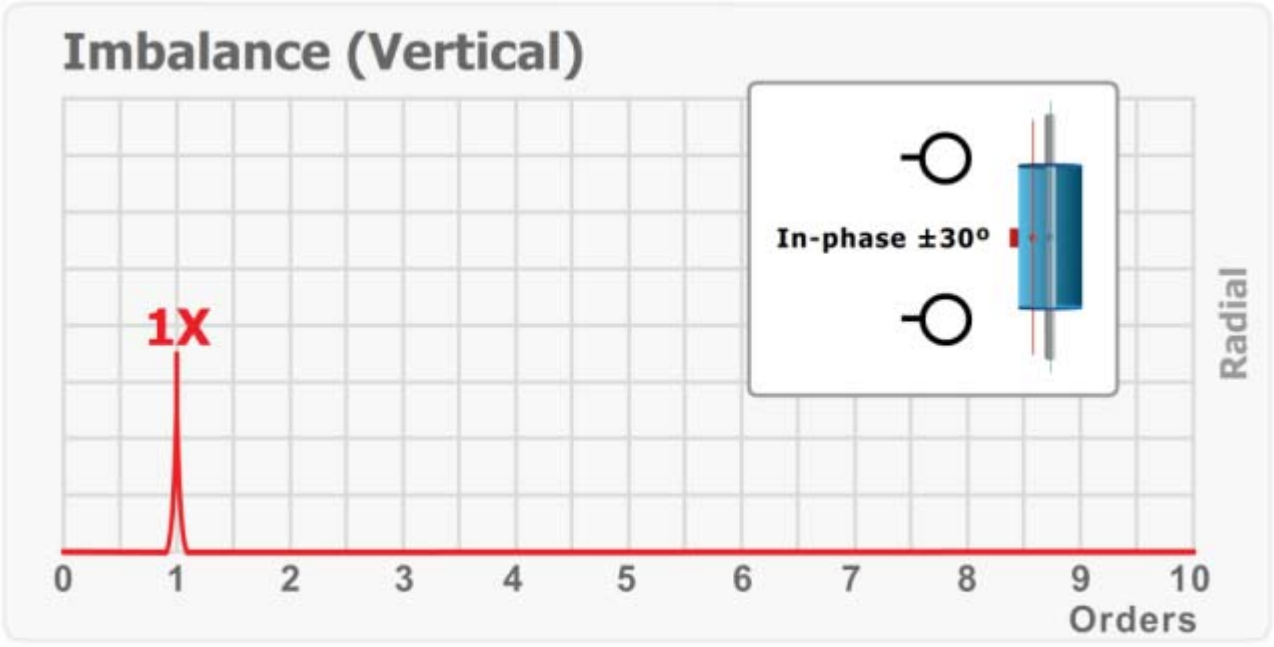
Phase: Look for 90° phase shift between readings taken 90° apart. All readings taken in the same direction should be in-phase.

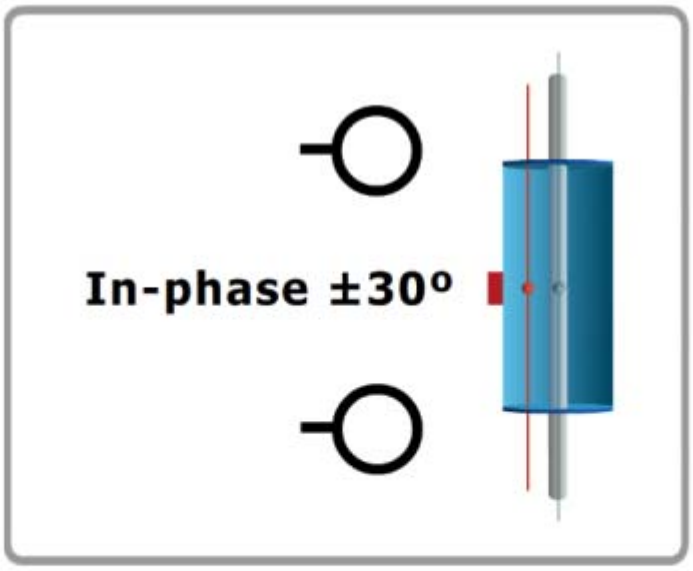
频谱：径向 1X 幅值高

时域波形：采用速度单位时，时域波形将是正旋波。

幅值：刚度最小的地方，振值会最高。通常电机的顶部会最高，沿着管道方向会最小。

相位：同一方向上的相位应该一致。





1.5 Unbalance: Overhung machines 悬臂设备

Symptoms: High 1X axial, 1X radial (V & H)特征：1X 轴向高，1X 径向（V & H）

In an overhung or cantilevered machine, you will see a high amplitude peak at 1X turning

在悬臂设备上，你会看到垂直、水平、轴向的 1X 幅值较高。

speed in the vertical, horizontal and axial directions.

We see the high 1X in axial because the unbalance creates a bending moment on the shaft, causing the bearing housing to move axially. Examples of overhung rotors are close-coupled pumps, axial flow fans, and small turbines.

Spectrum: High 1X in the radial directions but highest in the axial direction.

Waveform: The waveform will be very sinusoidal when viewed in units of velocity.

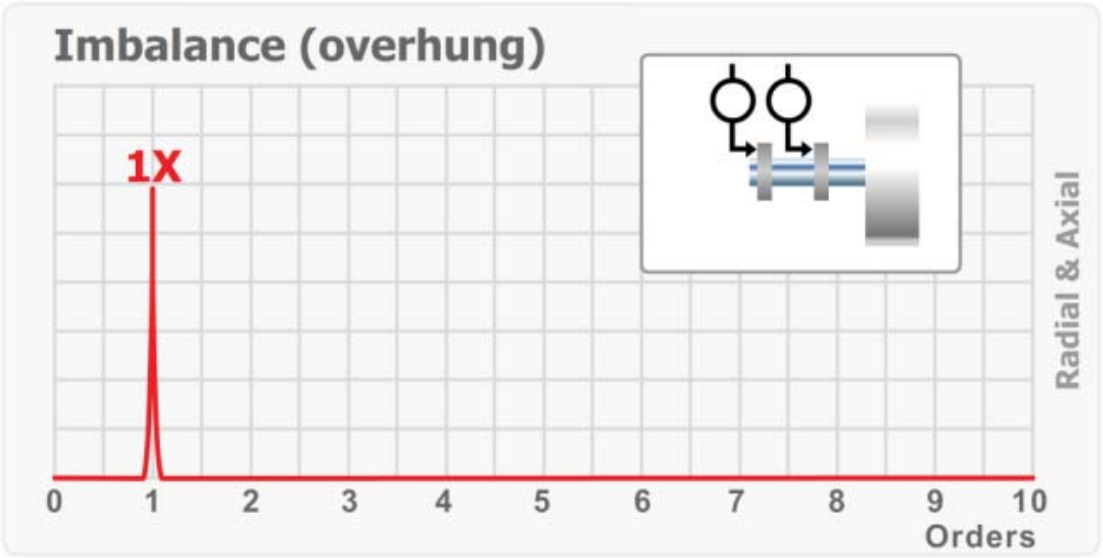
Phase: Look for 90° phase shift between vertical and horizontal. Axial readings on both bearings will be in-phase. Radial phase readings on both bearings will be in-phase.

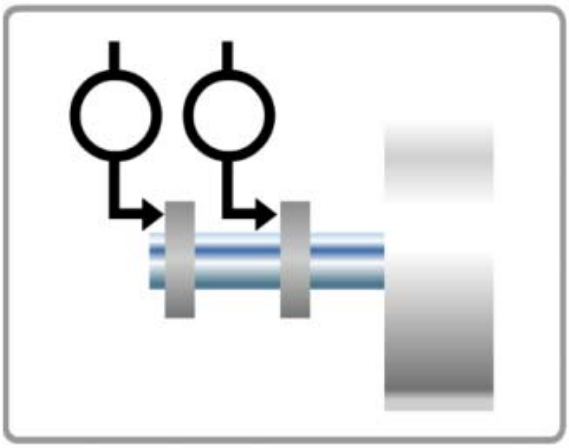
我们看到 1X 轴向高，是因为不平衡对转子产生了弯矩，导致轴承箱沿轴向移动。典型的悬臂转子如：悬臂泵、轴流风机、小型汽轮机。

频谱：1X 径向高，但是 1X 轴向最高

时域波形：采用速度单位，时域波形是正旋波。

相位：同一轴承位置的水平和垂直相位差 90°。两侧轴承轴向的相位一致，径向相位一致。





2 Analysis Definitions: Misalignment 不对中

Frequency: 1X axial, 2X radial (V & H)频率 1X 轴承，2X 径向（V & H）

Misalignment is a condition where the centerlines of coupled shafts do not coincide. Misalignment is common due to poor alignment practices or because of thermal growth, shifting foundations, pipe strain, etc.

不对中就是联轴器两侧轴的中心线不重合。由于对中经验不足或热膨胀、基础移位、管道应力或等，不对中很常见。

If the misaligned shaft centerlines are parallel but not coincident, then the misalignment is said to be parallel (or offset) misalignment. > If the misaligned shafts meet at a point but are not parallel, then the misalignment is called angular misalignment. The vibration does not always change in predictable ways when shafts are misaligned.

如果不对中轴的中心线是平行的，但是没有重合，那么这种不对中被认为是平行不对中。如果不对中轴的中心线相交于一点，那么这种不对中被认为是角不对中。当轴不对中时，振动变化并不总是按照预测的方式发展不总是可以预测的。

Most misalignment cases are a combination of parallel and angular misalignment. Diagnosis, as a general rule, is based upon dominant vibration at twice the rotational rate (2X) with increased rotational rate (1X) levels acting in the axial and in either the vertical or horizontal directions.

大多数情况下，不对中是平行不对中和角不对中的组合。一般的诊断原则，轴向、垂直或水平方向，2X 是主导频率，1X 幅值逐渐升高。

Spectrum: We expect to see a high 1X peak in the axial direction due to angular (gap) misalignment, and high peaks at 1X, 2X, 3X, and even 4X and 5X in the radial direction due to the parallel (offset) misalignment.

频谱：对于角不对中，我们会看到 1X 轴向幅值高；对于平行不对中，我们会看到 1X、2X、3X，甚至是 4X、5X 的径向幅值高。

The peaks may be higher in vertical at one end of the component (e.g. motor) but higher in horizontal at the other end of the same component.

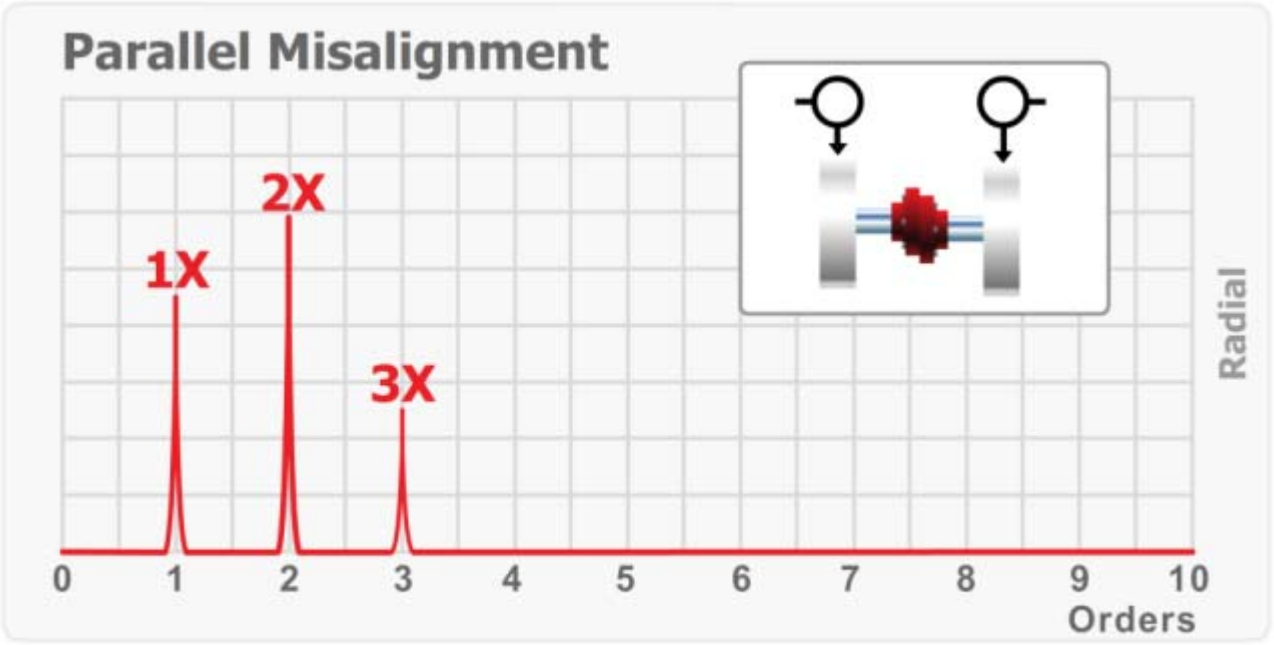
在部件（如电机）的一端垂直方向振动更大，而在其另一端，水平方向更大。

Phase: The components (e.g. motor and pump) will be out-of-phase axially due to angular misalignment. When comparing vertical and horizontal phase readings, they may be in-phase **or** 180° out-of-phase. Vertical phase readings taken on opposites sides of the coupling (e.g. motor drive end and pump drive end) will be out-of-phase.

相位：由于角不对中，部件间的轴向相位反向。当比较垂直和水平相位读数时，可能是 0 或 180°。联轴器两侧（电机驱动端和泵驱动端）垂直相位会是反向。

Waveform: The waveform will be a combination of 1X, 2X and possibly other sources and may therefore include a "wobble" or take on the "M" or "W" shape.

时域波形：时域波形将是 1X、2X 或其它频率的组合，因此形状会是“M”,“W”。



2.1 Misalignment: Parallel (Offset)平行不对中

Symptoms: 2X radial, small 1X radial (V & H)特征 2X 径向，1X 径向较小（(V & H）

If the misaligned shaft centerlines are parallel but not coincident, then the

如果不对中轴的中心线是平行的，但是

misalignment is said to be parallel (or offset) misalignment.

没有重合，那么这种不对中被认为是平行不对中。

Misalignment is common due to poor alignment practices or because of thermal growth, shifting foundations, pipe strain, etc. The vibration does not always change in predictable ways when shafts are misaligned.

由于热膨胀、基础移位、管道应力或对中经验不足等，不对中很常见。

Parallel misalignment produces both a shear force and bending moment on the coupled end of each shaft. Spectrum measurements are very useful; however it can be confused with other faults. Phase readings provide additional evidence.

平行不对中会对耦合的两根轴的末端产生剪切力和弯矩。频谱测量是很有用的；但是它可能和其它故障混淆。相位可以提供更多的证据。

Spectrum: We expect to see high peaks at 1X, 2X, 3X, and even 4X and 5X in the radial direction due to the parallel (offset) misalignment. 2X can be quite high compared to 1X vibration. The presence of 3X, 4X, 5X etc. will depend on coupling type and degree of misalignment.

频谱：对于平行不对中，我们会看到 1X、2X、3X，甚至是 4X、5X 的径向幅值高，2X 相比 1X 可以更高。3X、4X、5X 等取决于联轴器的类型和不对中的程度。

The peaks may be higher in vertical at one end of the component (e.g. motor) but higher in horizontal at the other end of the same component.

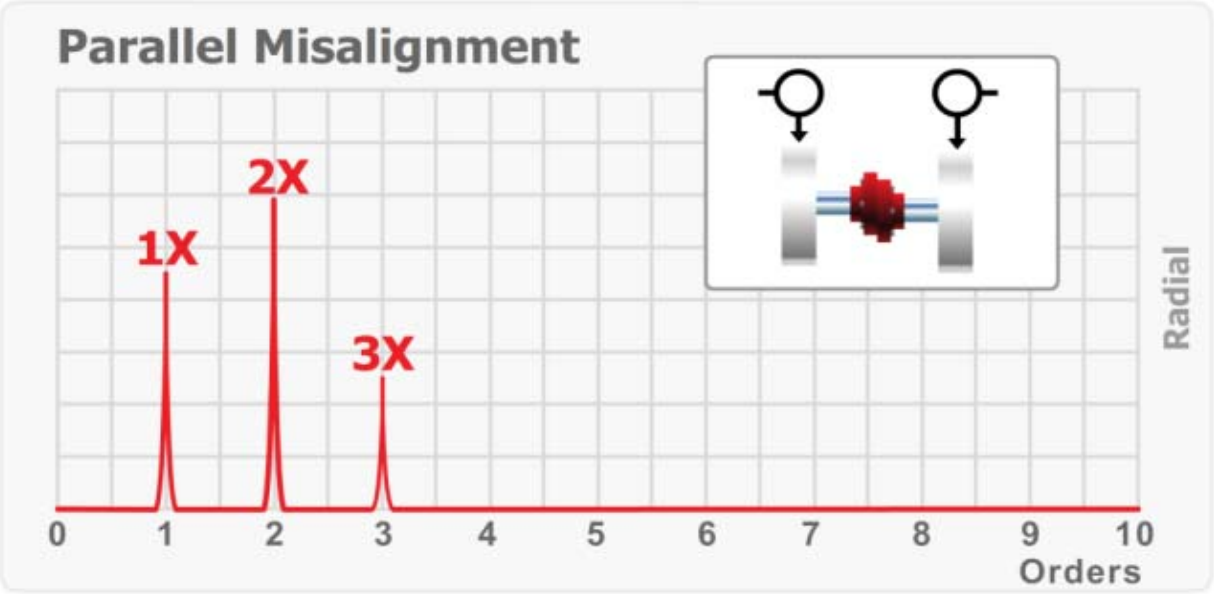
在部件（如电机）的一端垂直方向振动更大，而在其另一端，水平方向更大。

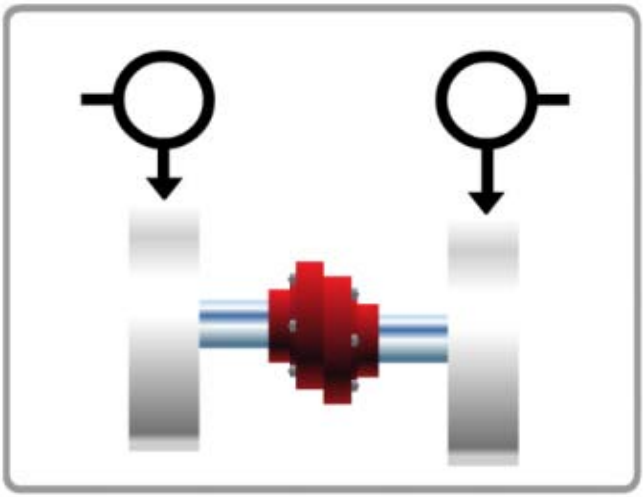
Phase: When comparing vertical and horizontal phase readings, they may be in-phase or 180° out-of-phase. Vertical phase readings taken on opposites sides of the coupling (e.g. motor drive end and pump drive end) will be out-of-phase.

相位：比较垂直和水平相位读数时，可能是 0 或 180°。联轴器两侧（电机驱动端和泵驱动端）垂直相位会是反向。

Waveform: The waveform will be a combination of 1xTS, 2xTS and possibly other sources and may therefore include a "wobble" or take on the "M" or "W" shape.

时域波形：时域波形将是 1X、2X 或其它频率的组合，因此形状会是“M”,“W”。





2.2 Misalignment: Angular (Gap)角不对中

Symptoms: 1X axial, small 2X axial, small 1X radial 特征：1X 轴向，2X 轴向较小，1X 径向较小

If the misaligned shafts meet at a point but are not parallel, then the misalignment is called angular or gap misalignment.

如果不对中轴的中心线相交于一点而不是平行的，那么这种不对中被认为是角不对中。

Misalignment is common due to poor alignment practices or because of thermal growth, shifting foundations, pipe strain, etc. The vibration does not always change in predictable ways when shafts are misaligned.

Angular misalignment produces a bending moment on each shaft, and this generates a strong vibration at 1X and some vibration at 2X in the axial direction at both bearings.

There will also be fairly strong radial (vertical and horizontal) 1X and 2X levels, however these components will be in phase.

Spectrum: We expect to see a high 1X peak in the axial direction, and a small 2X and 3X peak depending upon the "linearity" of the vibration. There may also be 1X and 2X in the radial direction.

Phase: The components (e.g. motor and pump) will be out-of-phase axially due to angular misalignment. Measure axially on the components on either side of the coupling and remember to compensate for sensor direction. The components are likely to be out-of-phase radially across the coupling.

Waveform: The waveform in the axial direction will be dominated by the sinusoidal 1X vibration.

由于热膨胀、基础移位、管道应力或对中经验不足等，不对中很常见。当轴不对中时，产生的振动不总是可以预测的。

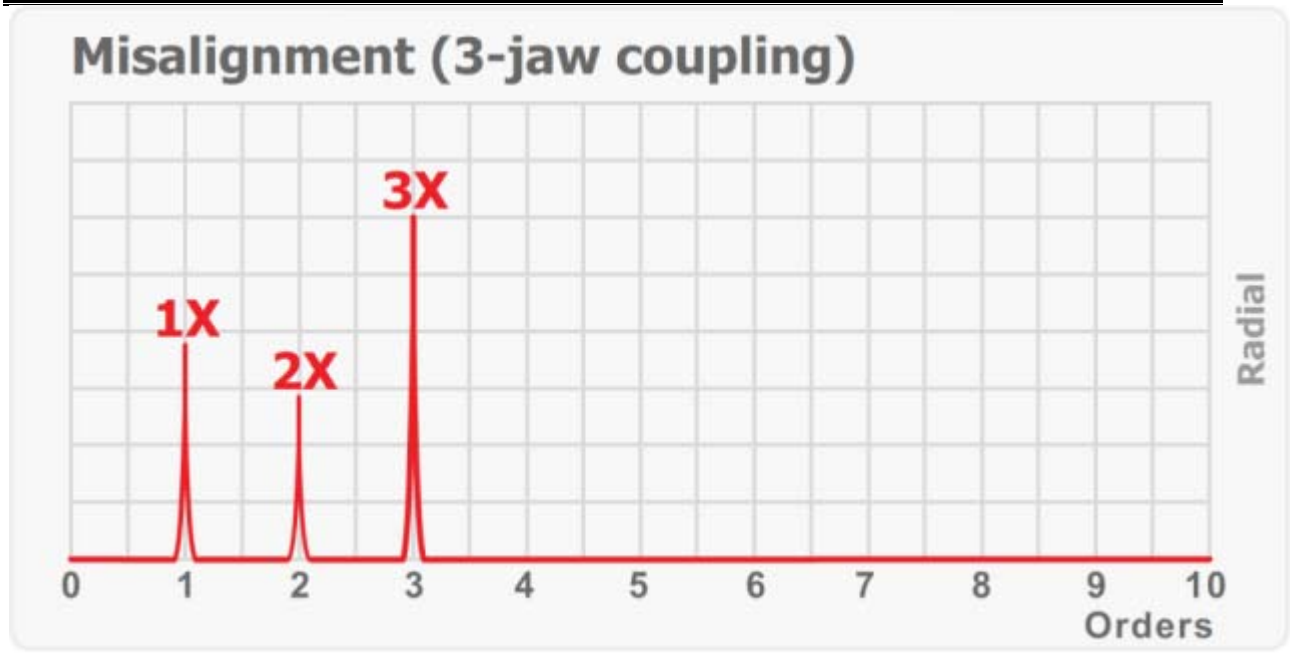
角不对中会对耦合的每根轴产生弯矩，两个轴承位的轴向上产生较大的 1X 和较小 2X 幅值。

径向（水平和垂直）也会产生相当大的 1X 和 2X 幅值。但是这些部件会是同相的。

频谱：我们看到轴向 1X 幅值高，2X 幅值小，3X 取决于振动的“线性”，可能径向会存在 1X 和 2X。

相位：由于角不对中，部件间（电机驱动端和泵驱动端）的轴向相位反向。测量联轴器两侧部件的轴向相位，注意传感器方向相同。联轴器两侧径向相位会是反向。

时域波形：轴向 1X 占主导的正旋波。



3 Analysis Definitions: Rolling element bearings 滚动轴承

Symptoms: Non-synchronous vibration and others 特征：非同步振动和其它

There are a large number of fault conditions that can be associated with rolling element

跟滚动轴承相关的故障有很多，如：1-4

bearings, including: stage one-four bearing wear, lubrication problems, cocked bearing, fluting/EDM, skidding, and looseness. We have included information on each of these possible fault conditions in this app.

- Lubrication: Insufficient lubrication.
- Wear/cracks/spalls: Damage on the inner or outer race and damage on the rolling elements. Damaged cages are harder to detect with vibration analysis.
- Fluting/EDM: Current passing through bearing – washboard pattern etched on raceways.
- Cocked bearing: Inner race not true on shaft or outer race not true in housing.
- Excessive clearance: Due to excessive wear or poor bearing selection.
- Skidding: Rolling elements skidding over inner race when out of the load zone.
- Loose on shaft: Inner race sliding on shaft.
- Loose in housing: Outer race turning in housing.

Spectrum analysis is very useful, but time waveform analysis should also be used. High frequency techniques (Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™) are very effective at detecting many of the fault conditions.

Lubrication: High frequency vibration.

Wear/cracks/spalls High frequency vibration initially, extending into lower frequency vibration as the fault becomes worse. Non-synchronous frequencies.

Fluting/EDM: Raised noise floor with peaks in range 100-180 kCPM.

Cocked bearing: Axial vibration – phase readings on face of component aid in the diagnosis.

Excessive clearance: High harmonics of turning speed (1X).

Skidding: Raised noise floor with peaks in range 100-180 kCPM.

Loose on shaft: 3X peak with harmonics.

Loose in housing: 4X peak.

阶段的轴承磨损、润滑故障、翘曲轴承、电蚀、打滑、松动。

●润滑：润滑不良

●磨损/裂纹/剥落：内圈或外圈和滚子损伤。振动分析监测保持架损伤故障比较困难。

●电蚀：电流通过轴承-搓衣板图案会蚀刻在滚道上。

●翘曲轴承：内圈与转轴安装虚位，外圈与轴承箱安装虚位。

●间隙过大：过度磨损或轴承选择错误。

●打滑：当在非负载区，滚子在内滚道上打滑。

●内圈松动：内圈在轴上转动。

●外圈松动：外圈在轴承箱内转动。

频谱分析是很有用的，但是也应该使用时域波形。高频技术（包络、解调、PeakVue™、 Shock Pulse™ 、Spike Energy™）在监测多种轴承故障上，也是很有用的。

润滑：高频振动

磨损/裂纹/剥落：刚开始高频振动，当故障变得严重时，延伸至低频振动。非同步频率。

电蚀：100-180kCPM 范围内底部噪声的峰值。

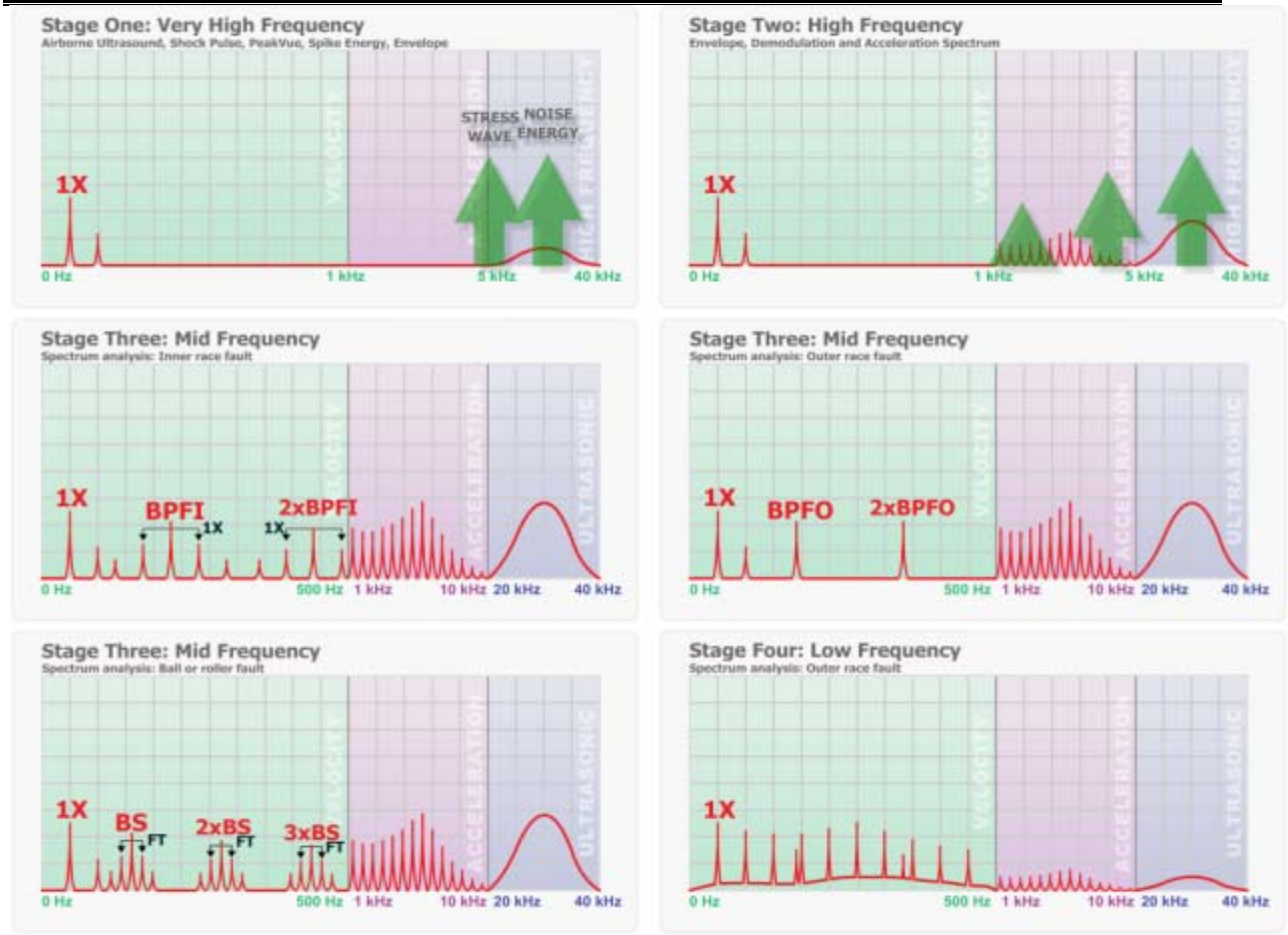
翘曲轴承：轴向振动-同一方向的相位辅助诊断。

间隙过大：1X 转频的高次谐频。

打滑：100-180kCPM 范围内底部噪声峰值。

内圈松动：3X 峰值与谐频

外圈松动：4X 峰值



3.1 Rolling element bearings: Stage one fault 滚道轴承：第一阶段故障

Symptoms: Very low amplitude, very high frequency vibration 特征：幅值低，高频振动

At the first signs of lack of lubrication or minor bearing damage the vibration

润滑不足或轻微轴承损伤的初步特征是

amplitude will be very low. The vibration generated will be very high frequency; possibly over 10 kHz.

振动幅值很低。产生的振动时很高频的。可能超过 10kHz。

Traditional spectrum analysis and time waveform techniques will not detect the fault. High frequency techniques such as ultrasound may detect the lubrication problem, and techniques such as Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™ may detect the fault in Stage One.

传统的频谱分析和时域波形技术不能监测到该故障。高频技术如超声可以监测润滑故障，包络、解调、PeakVue™、Shock Pulse™ 、Spike Energy™可以监测第一阶段故障。

Spectrum: Only spectra from the high frequency techniques will reveal a fault.

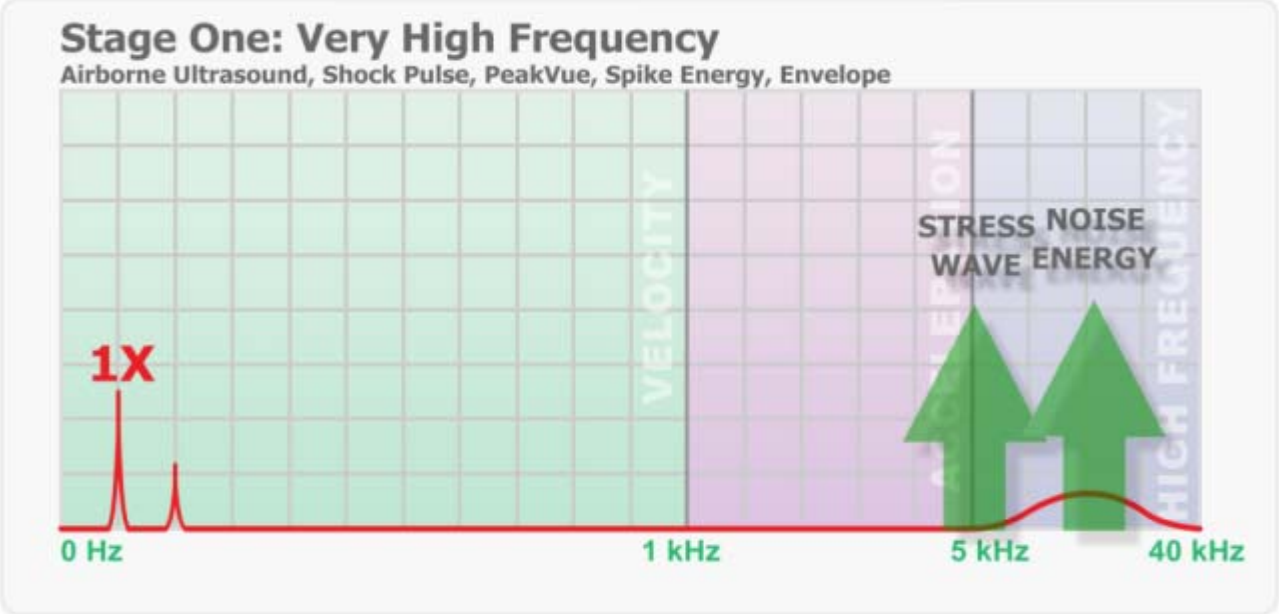
频谱：只有高频技术的频谱才能监测到该故障。

Waveform: Will not help in stage one

时域波形：在第一阶段，没有帮助。

High frequency techniques: Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™ may be effective but only if the filter is set correctly and the accelerometer (or shock pulse sensor) is correctly mounted.

高频技术：只有当滤波设置合理和加速度传感器（或 shock pulse 传感器）安装正确时，包络、解调、PeakVue™、Shock Pulse™ 、Spike Energy™可能有效果。



3.2 Rolling element bearings: Stage two fault 滚动轴承：第二阶段故障

Symptoms: Very low amplitude, very high frequency vibration 特征：幅值低，高频振动

As the bearing fault develops, techniques such as enveloping and demodulation will

随着轴承故障发展，包络和解调技术相

be more successful than when the fault was in Stage One, however it is unlikely that a linear velocity spectrum will indicate that the fault exists. If the spectrum is displayed in log format, or you use units of acceleration, there is a greater chance of success.

比较第一阶段更有用。但是在线性速度谱中不会显示故障。如果频谱采用对数方式或使用加速度单位，看到故障的几率会更大。

The time waveform viewed in units of acceleration will show signs of the defect, especially when applied to slow speed machines.

加速度单位的时域波形会显示故障的征兆，特别是应用在低速设备上。

PeakVue™, Shock Pulse™, Spike Energy™ can all be used successfully if set up correctly and the accelerometer is mounted correctly.

如果滤波设置合理和加速度传感器安装正确， PeakVue™、 Shock Pulse™ 、Spike Energy™都是有用的。

Spectrum: Only spectra from the high frequency techniques will reveal a fault.

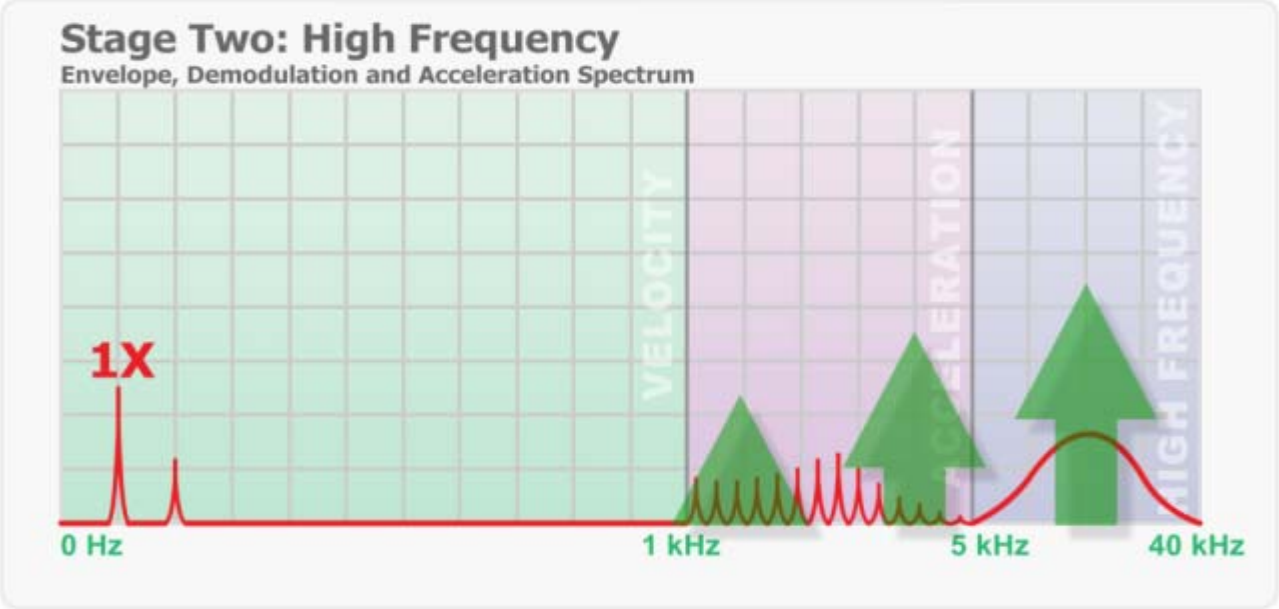
频谱：只有高频技术的频谱才能监测到该故障。

Waveform: May be effective. Most likely to be effective on slow speed machines.

时域波形：可能是有效的。在低速设备上可能最有效。

High frequency techniques: Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™ may be effective but only if the filter is set correctly and the accelerometer (or shock pulse sensor) is correctly mounted.

高频技术：只有当滤波设置合理和传感器（或 shock pulse 传感器）安装正确时，包络、解调、PeakVue™、 Shock Pulse™ 、Spike Energy™可以是有效的。



3.3 Rolling element bearings: Stage three fault: outer race 滚动轴承：第三阶段：外滚道

Symptoms: Non-synchronous harmonics 特征：非同步谐频

When the bearing fault reaches stage three the damage is more severe and will be visible if the bearing is removed. The

当轴承故障发展到第三阶段，损伤就比较严重了，如果拆下轴承，肉眼就能看

velocity spectrum can be used to detect the fault in addition to the time waveform (in velocity or acceleration) and high frequency techniques (demodulation, enveloping, PeakVue™, Shock Pulse™, and Spike Energy™).

见损伤。除了时域波形（速度或加速度单位）和高频技术（包络、解调、PeakVue™, Shock Pulse™, and Spike Energy™），速度谱也能监测该故障。

If the damage is on the outer race there will be an impact each time the ball or roller comes into contact with the damaged area. The amplitude should be constant, therefore no modulation (or sidebands). If the outer race is rotating there will be 1X sidebands.

如果损伤发生在外滚道，那么滚子接触损伤区域，就会发生一次撞击。幅值应该是一定的，因此也没有调制（边带）如果外圈旋转，就会有 1X 边带。

Spectrum: Look for harmonics of a frequency that is not an even multiple of shaft turning speed (e.g. 4.31X). If the inner race is rotating you should not expect to find sidebands.

频谱：查找非整数倍转频（如，4.31X）的谐频。如果轴承上内圈旋转，不应该看到边带。

BPFI>BPFO>BSF>1X>FT

BPFI + BPFO = NB

½-(1.2/NB)

BSF~½[(NB/2)-(1.2/NB)]

BPFO≈(NB/2)-1.2

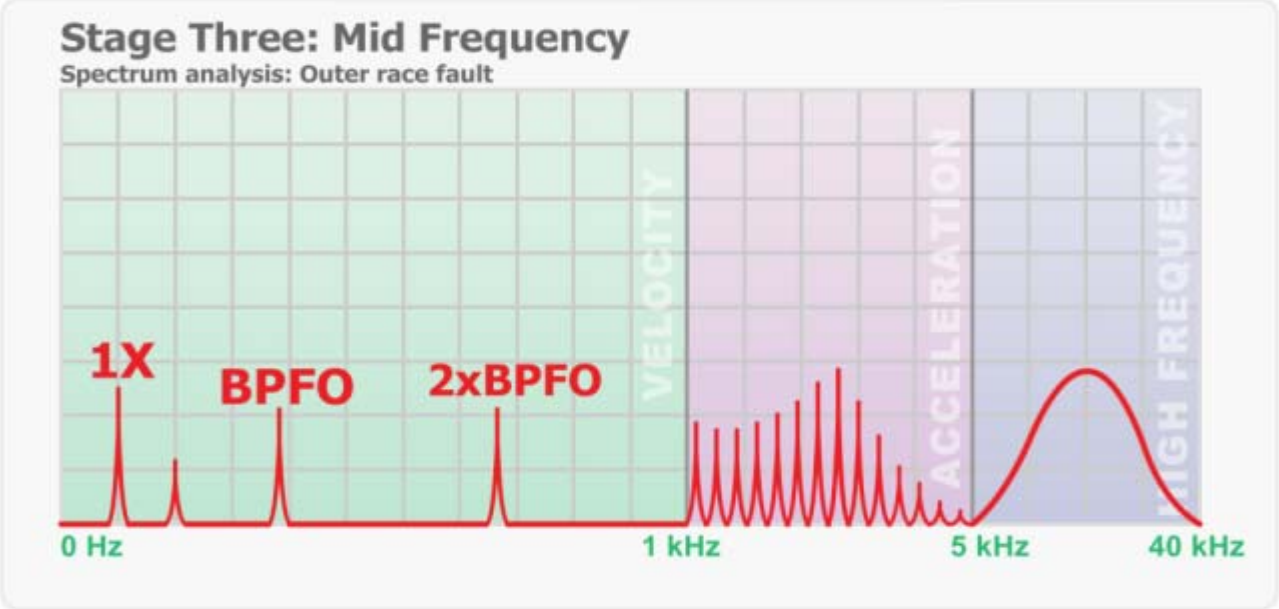
BPFI≈(NB/2)+1.2

Waveform: Impacts should be visible in the time waveform. You will need to have a large number of samples and a small number of shaft rotations to view the impacts.

时域波形：时域波形上能看到冲击。采样频率和采样时间设置合理，才能看到冲击。

High frequency techniques: Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™ may be effective but only if the filter is set correctly and the accelerometer (or shock pulse sensor) is correctly mounted.

高频技术：只有当滤波设置合理和传感器（或 shock pulse 传感器）安装正确时，包络、解调、PeakVue™、 Shock Pulse™ 、Spike Energy™可以是有效的。



3.4 Rolling element bearings: Stage three fault: inner race 滚道轴承：第三阶段：内滚道

Symptoms: Non-synchronous harmonics & 1X sidebands 特征：非正式倍&1X 边带

When the bearing fault reaches stage three the damage is more severe and will be visible if the bearing is removed. The

当轴承故障发展到第三阶段，损伤就比较严重了，如果拆下轴承，肉眼就能看见损

velocity spectrum can be used to detect the fault in addition to the time waveform (in velocity or acceleration) and high frequency techniques (demodulation, enveloping, PeakVue™, Shock Pulse™, and Spike Energy™).

If the damage is on the inner race there will be an impact each time the ball or roller comes into contact with the damaged area. The amplitude will be highest when the damaged area is in the load zone therefore there will be 1X sidebands.

Spectrum: Look for harmonics of a frequency that is not an even multiple of shaft turning speed (e.g. 6.31X) with 1X sidebands. If the outer race is rotating you should not expect to find sidebands.

BPFI>BPFO>BSF>1X>FT

BPFI + BPFO = NB

FT≈½-(1.2/NB)

BSF~½[(NB/2)-(1.2/NB)]

BPFO≈(NB/2)-1.2

BPFI≈(NB/2)+1.2

Waveform: Impacts should be visible in the time waveform. You will need to have a large number of samples and a small number of shaft rotations to view the impacts.

High frequency techniques: Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™ may be effective but only if the filter is set correctly and the accelerometer is correctly (or shock pulse sensor) mounted.

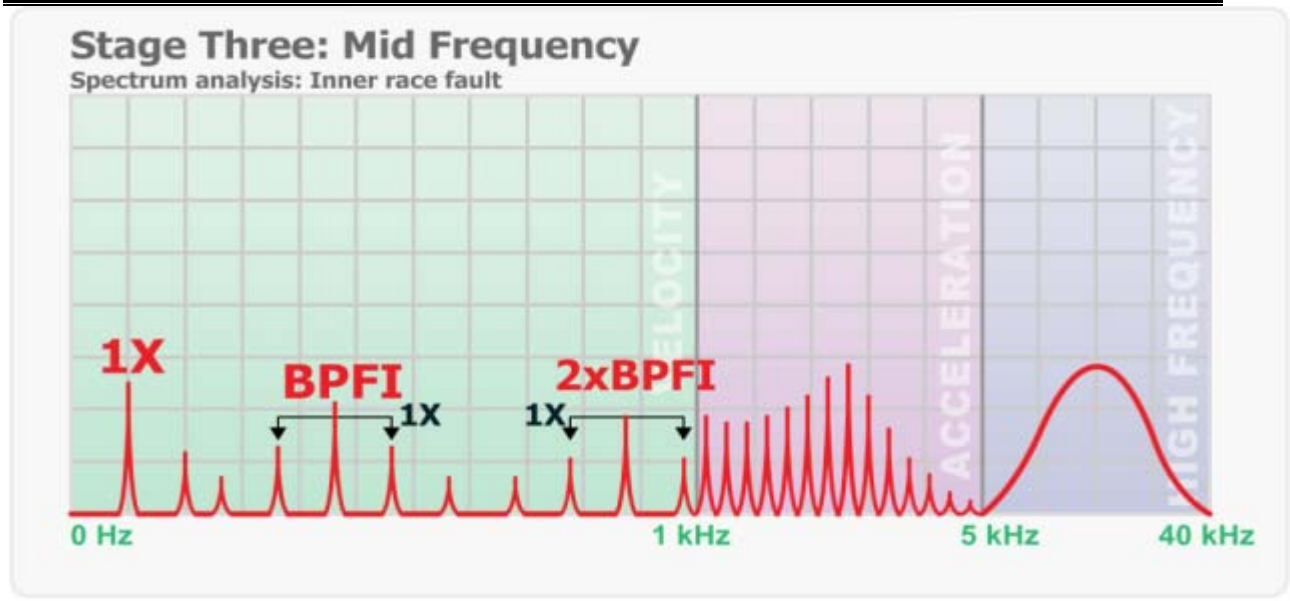
伤。除了时域波形（速度或加速度单位）和高频技术（包络、解调、PeakVue™, Shock Pulse™, and Spike Energy™），速度谱也能监测该故障。

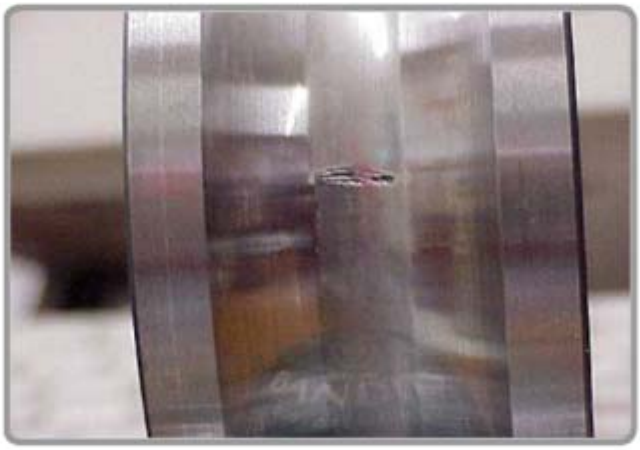
如果损伤发生在轴承内滚道，那么滚子接触损伤区域，就会发生一次撞击。当损伤区域进入负载区时，幅值会最高，所以会有 1X 边带。

频谱：查找非整数倍转频±1X 边带（如，6.31X）的谐频。如果轴承上外圈旋转，不应该看到边带。

时域波形：时域波形上能看到冲击。采样频率和采样时间设置合理，才能看到冲击。

高频技术：只有当滤波设置合理和传感器（或 shock pulse 传感器）安装正确时，包络、解调、PeakVue™、Shock Pulse™、Spike Energy™可以是有效的。





3.5 Rolling element bearings: Stage three fault: ball damage 滚动轴承：第三阶段：滚子损伤

Symptoms: Non-synchronous harmonics & FTF sidebands 特征：非同步谐频&FTF 边带

When the bearing fault reaches stage three the damage is more severe and will be

当轴承故障发展到第三阶段，损伤就比

visible if the bearing is removed. The velocity spectrum can be used to detect the fault in addition to the time waveform (in velocity or acceleration) and high frequency techniques (demodulation, enveloping, PeakVue™, Shock Pulse™, and Spike Energy™).

较严重了，如果拆下轴承，肉眼就能看见损伤。除了时域波形（速度或加速度单位）和高频技术（包络、解调、PeakVue™, Shock Pulse™, and Spike Energy™），速度谱也能监测该故障。

If the damage is on the balls or rollers there will be an impact each time the damaged area comes into contact with the inner or outer race. The amplitude will be highest when the damaged ball is in the load zone therefore there will be FTF (cage) sidebands.

如果损伤发生在滚子上，那么损伤区域接触内滚道或外滚道，就会发生一次撞击。当损伤滚子进入负载区时，幅值会最高，所以会有 FTF 边带。

Spectrum: Look for harmonics of a frequency that is not an even multiple of shaft turning speed (e.g. 3.31X) with FTF (cage) sidebands (approx 0.46X).

频谱：查找非整数倍转频（如，3.31X）±FTF 边带（约 0.46X）的谐频。

BPFI>BPFO>BSF>1X>FT

BPFI + BPFO = NB

FT≈½-(1.2/NB)

BSF~½[(NB/2)-(1.2/NB)]

BPFO≈(NB/2)-1.2

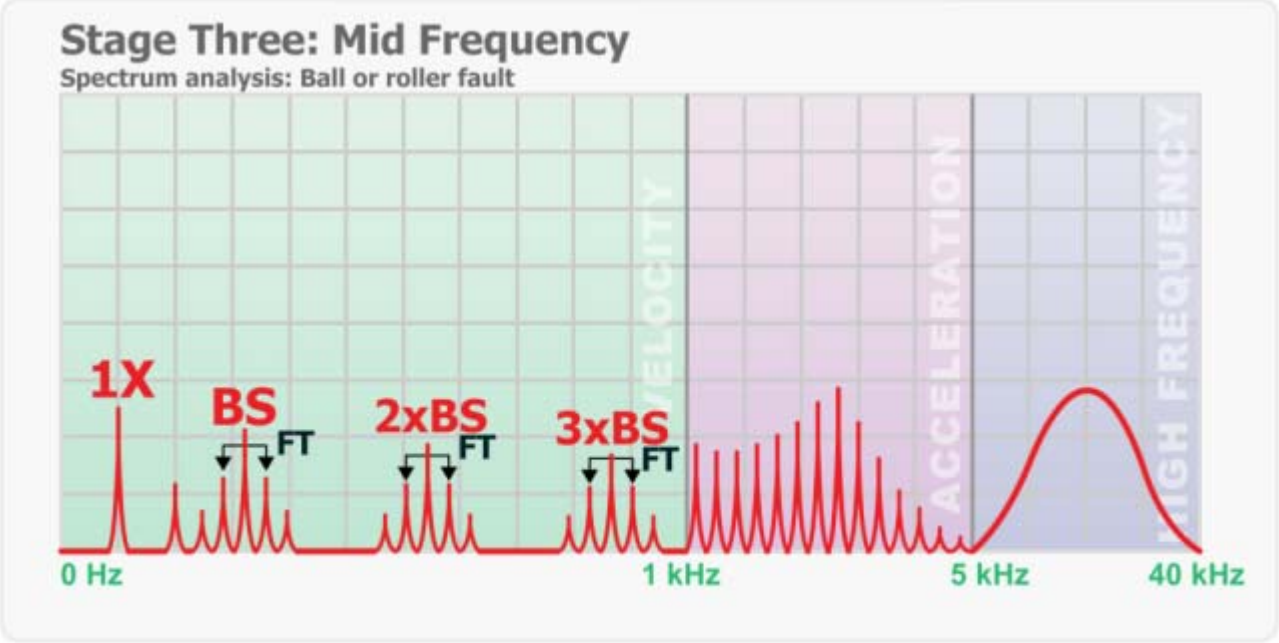
BPFI≈(NB/2)+1.2

Waveform: Impacts should be visible in the time waveform. You will need to have a large number of samples and a small number of shaft rotations to view the impacts.

时域波形：时域波形上能看到冲击。采样频率和采样时间设置合理，才能看到冲击。

High frequency techniques: Enveloping, Demodulation, PeakVue™, Shock Pulse™ and Spike Energy™ may be effective but only if the filter is set correctly and the accelerometer (or shock pulse sensor) is correctly mounted.

高频技术：只有当滤波设置合理和传感器（或 shock pulse 传感器）安装正确时，包络、解调、PeakVue™、 Shock Pulse™ 、Spike Energy™可以是有效的。



3.6 Rolling element bearings: Stage four fault 滚动轴承：第四阶段故障

Symptoms: Non-synchronous harmonics & noise 非同步谐频&噪声

When the bearing fault reaches stage four the bearing has significant damage and should be replaced. The calculated forcing

当轴承故障达到第四阶段，轴承有了明显的损伤，应该更换。由于轴承部件的

frequencies may change due to changes in geometry. With time the tell-tale harmonics and sidebands may disappear. Instead the noise floor will rise up and methods such as Shock Pulse™ may trend downwards. As the clearance in the bearing increases due to wear, you will see signs of looseness (1X harmonics).

High frequency techniques become less effective as the condition worsens. Overall levels will increase, and the velocity spectrum will show the fault clearly.

Spectrum: Expect classic non-synchronous harmonics and sidebands to disappear. Spectrum will become very noisy – the noise floor will lift up ("haystacks" will appear in certain areas). As clearance increases, look for 1X harmonics.

Waveform: As vibration becomes noisier and more random, the waveform will also become noisier and less useful.

High frequency techniques: As the damage becomes more severe, the periodicity is lost, and the high frequencies are no longer generated. The noise floor of envelop spectra will rise up and swallow the peaks. Shock Pulse™ and Spike Energy™ may trend downwards.

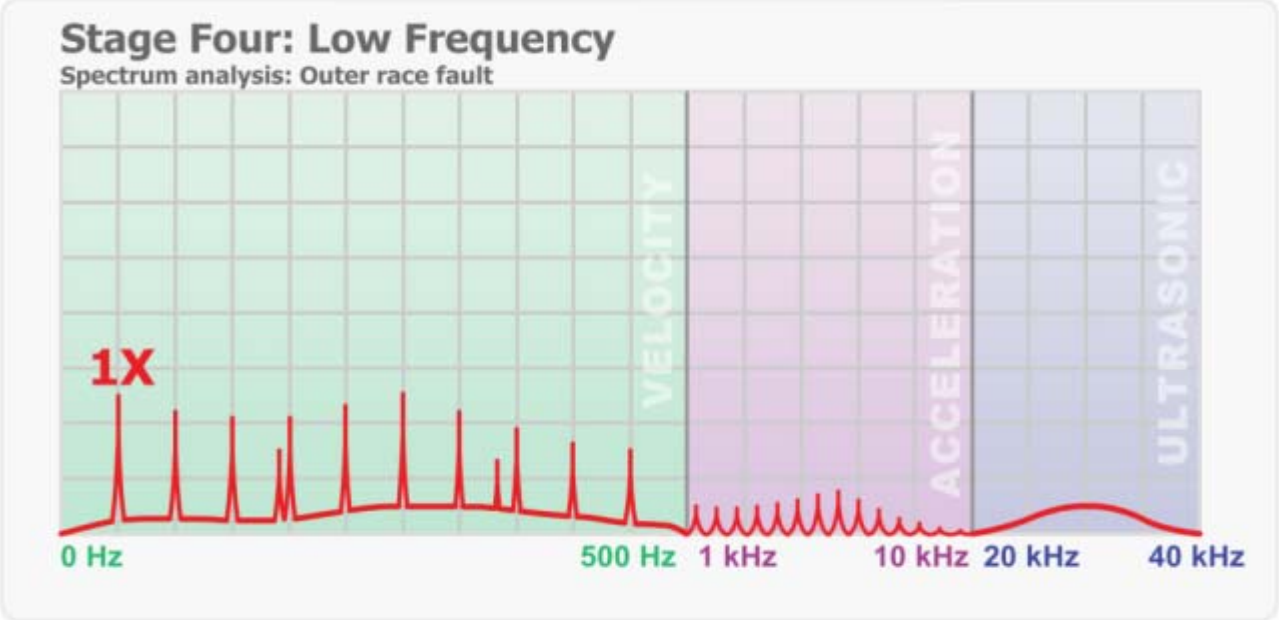
几何形状发生了变化，所以故障频率也会改变。随着时间发展，先前的故障频率及边带可能会消失。相反底部噪声会抬起，而 Shock Pulse™趋势值会变小。由于磨损，轴承的间隙会变大，你会看到松动的特征（1X 谐频）。

随着故障恶化，高频技术变的不太有效。总值会增加，速度谱会明显看到故障。

频谱：我们会看到非同步谐频和边带会消失。频谱底部噪声会抬起（“干草堆”会出现某些区域）。由于间隙变大，查看 1X 谐频。

时域波形：当振动越来越随机，噪声越来越大，时域波形噪声也会变大，用途会变小。

高频技术：当损伤越来越严重，周期性就会消失，不会再产生高频。包络谱底部噪声会抬起并淹没峰值。Shock Pulse™ 、 Spike Energy™趋势值降低。



3.7 Rolling element bearings: Cocked bearing: on shaft 滚动轴承：翘曲轴承：转轴上

Symptoms: 1X, 2X, and 3X axial 特征：1X、2X、3X 轴向

A cocked bearing, which is a form of misalignment, will generate considerable

翘曲轴承是不对中的一种形式，会产生

axial vibration. Peaks will often be seen at 1X, 2X, as well as 3X.

The bearing can be cocked on the shaft or in the housing. If it is cocked on the shaft then it will "wobble" as it rotates generating a rotating vibration – phase can detect this vibration.

Given that there is such a strong axial vibration, it can be confused with misalignment, and with unbalance in an overhung pump or fan. The presence of peaks at 2X and 3X would indicate a cocked bearing condition over unbalance however.

Use phase to accurately diagnose this condition.

Spectrum: Look for a raised 1X and 2X peak. Phase is the key indicator.

Phase: Take readings at 12:00, 3:00, 6:00 and 9:00 (or at any four positions 90° apart). The vibration amplitude should be similar at those positions but the phase should change by approximately 90°. You can do this with a two-channel analyzer by comparing 12:00 to 3:00, and then 3:00 to 6:00 etc.

相当大的轴向振动，常常会看到 1X、2X 以及 3X。

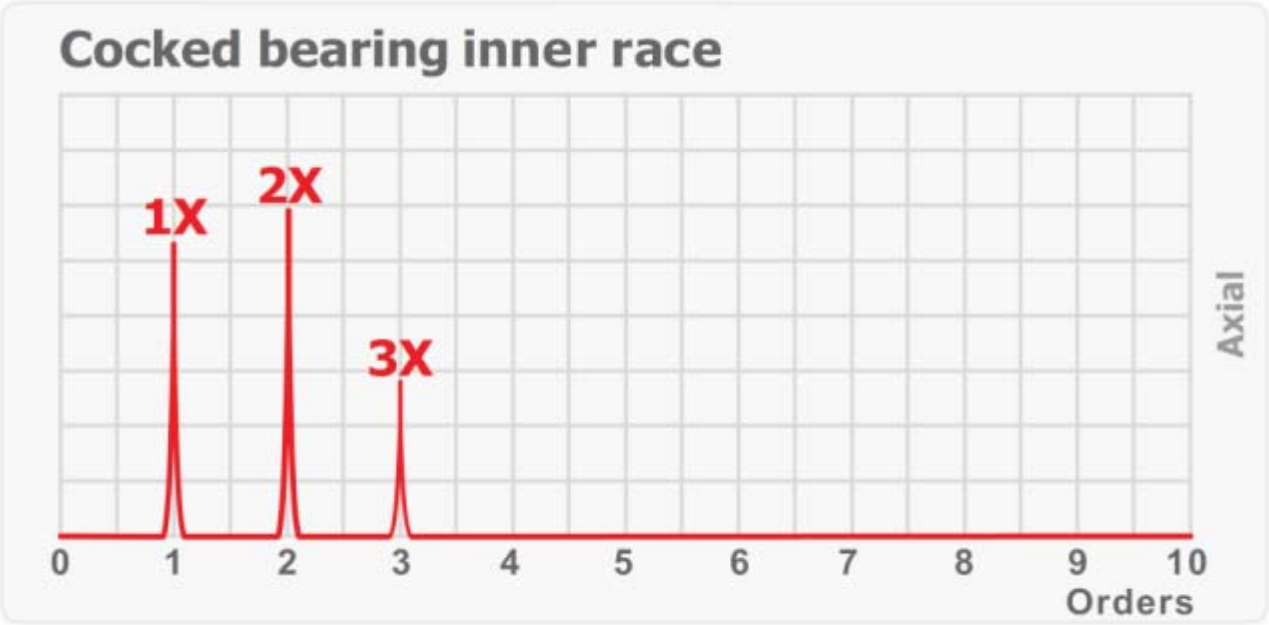
轴承可以在转轴和轴承箱上发生翘曲。如果翘曲发生在转轴上，旋转时会“抖动”，相位可以检测到该振动。

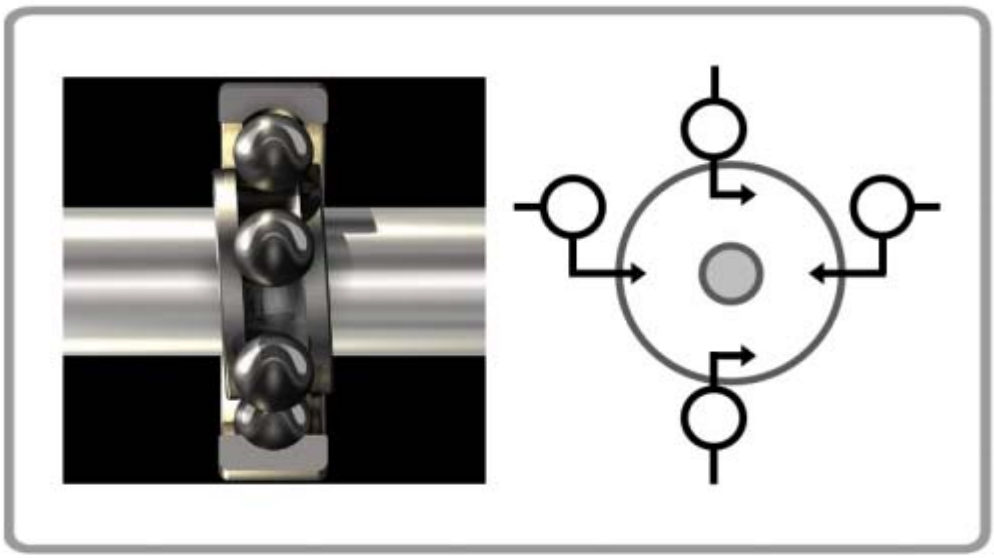
考虑到会产生很大的轴向振动，该故障会和不对中、悬臂转子不平衡发生混淆。但是频谱 2X、3X 会指示轴承翘曲，而非不平衡。

使用相位可以精确诊断该故障。

频谱：查看 1X、2X，相位是关键指示。

相位：在 12:00, 3:00, 6:00 ,9:00 方向（或任何相差 90 的四个方向）采集数据，振动幅值应该接近，但是相位会变化约 90°。也可使用双通道相位差功能，比较 12:00 - 3:00, 3:00- 6:00 的相位。





3.8 Rolling element bearings: Cocked bearing: in housing 滚动轴承：翘曲轴承：轴承箱内

Symptoms: 1X, 2X, and 3X axial 特征：1X、2X、3X 轴向

A cocked bearing, which is a form of misalignment, will generate considerable

翘曲轴承是不对中的一种形式，会产生

axial vibration. Peaks will often be seen at 1X, 2X, as well as 3X.

The bearing can be cocked on the shaft or in the housing. If it is cocked in the housing then the vibration will more closely mimic misalignment. There will be two points on either side of the shaft on the face of the component where the amplitude will be highest and the vibration will be 180° out-of-phase.

Given that there is such a strong axial vibration, it can be confused with misalignment, and with unbalance in an overhung pump or fan. The presence of peaks at 2X and 3X would indicate a cocked bearing condition over unbalance however.

Use phase to accurately diagnose this condition.

Spectrum: Look for a raised 1X and 2X peak. Phase is the key indicator.

Phase: Take readings on the bearing housing around the shaft and find the highest amplitude. Measure on the opposite side of the shaft and look for approximately 180° phase difference. Phase readings taken 90° from those points will not exhibit a 180° phase difference across the shaft.

相当大的轴向振动，常常会看到 1X、2X 以及 3X。

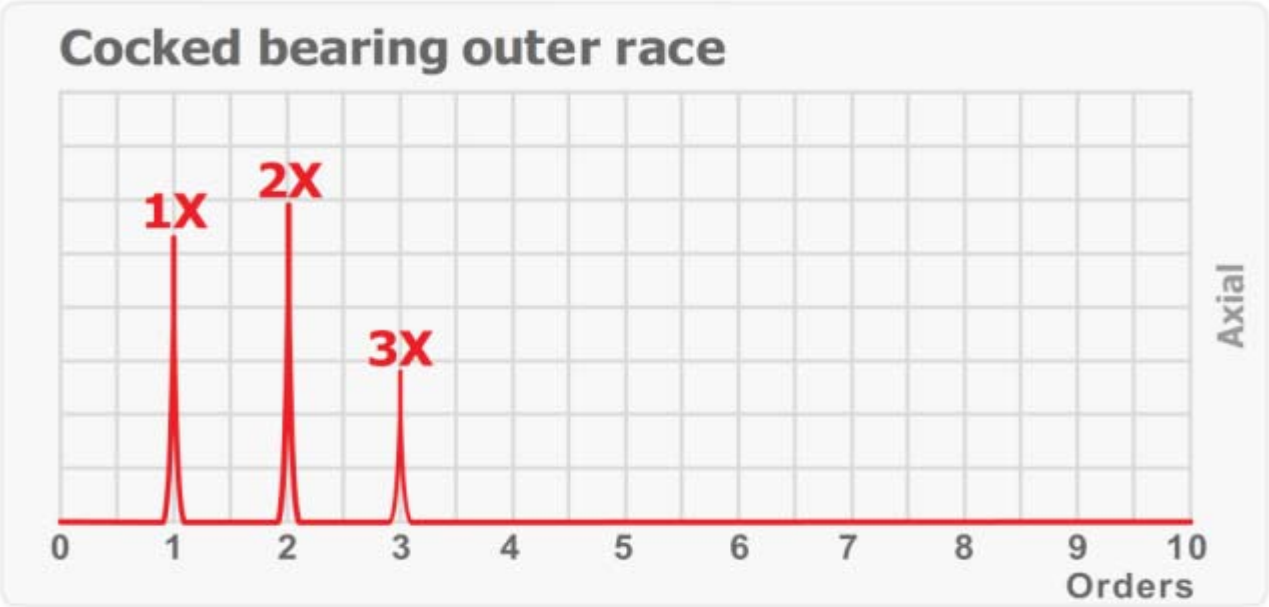
轴承可以在转轴和轴承箱上发生翘曲。如果翘曲发生在轴承箱上，振动模式很接近不对中。部件转轴两侧的点，振动幅值会最大，相位差 180°。

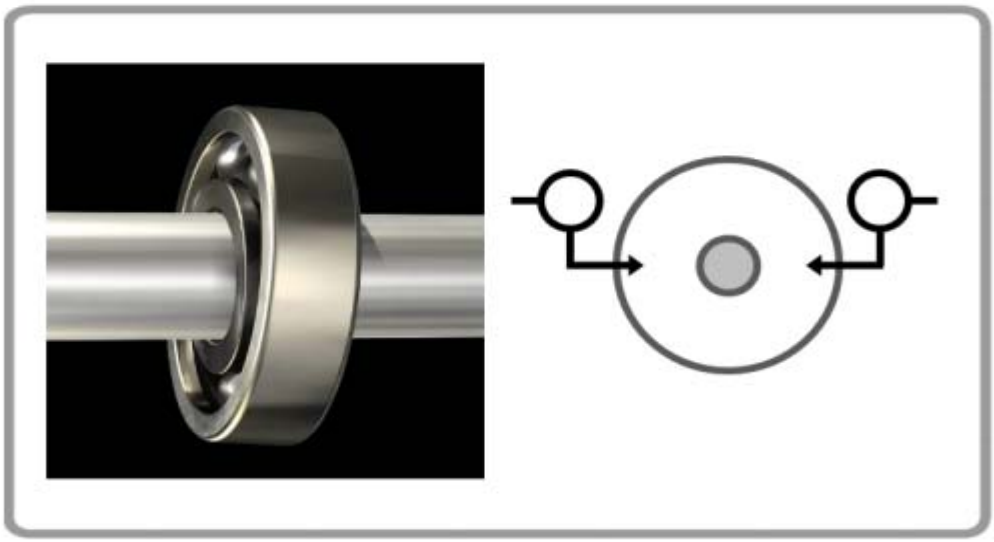
考虑到会产生很大的轴向振动，该故障会和不对中、悬臂转子不平衡发生混淆。但是频谱 2X、3X 会指示轴承翘曲，而非不平衡。

使用相位可以精确诊断该故障。

频谱：查看 1X、2X，相位时关键指示。

相位：绕着轴采集轴承箱的数据，找到最大幅值点，再测量轴的另一侧，相位差约 180°。从这些点的 90°方向测量的相位差不会是 180°。





3.9 Rolling element bearings: Fluting EDM 滚动轴承：电蚀

Symptoms: Series of peaks commonly between 100k CPM and 180k CPM 特征：

100k CPM-180k CPM 之间会有一系列常见峰值

Current passing through the bearings will damage the bearings. A rippled pattern will

电流通过轴承时会损伤轴承。当电弧发

be left on the bearing raceways as arcing occurs.

The spectrum will have a series of peaks at high frequency separated by BPFO.

This condition is common with DC motors and now with VFDs as well.

Spectrum: Often there will be a series of peaks that will rise up at a high frequency, commonly between approximately 100,000 CPM and 180,000 CPM (1600 Hz to 3000 Hz). The peaks are commonly spaced by the outer race BPFO frequency. It is believed that the vibration is exciting a resonance.

Waveform: The fault will be indicated, but the spectrum is the best tool.

HFD: Depending upon your filter settings, the HFD techniques should indicate that the bearing is emitting a higher level of high frequency vibration.

生时，搓衣板图案会蚀刻在轴承滚道上。

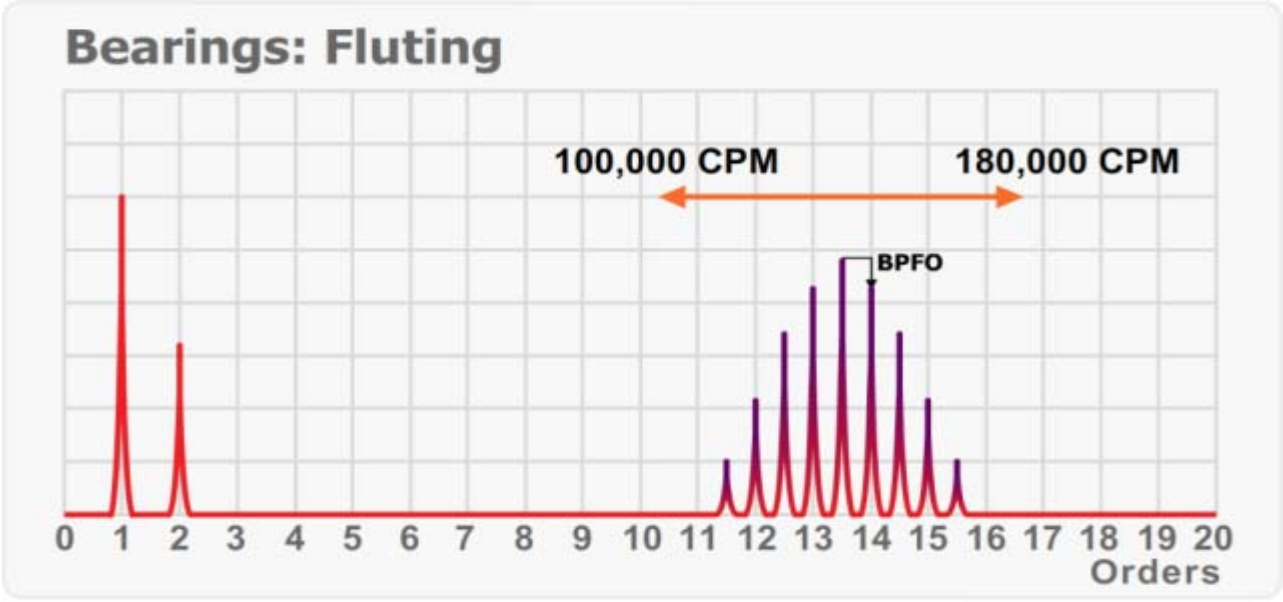
频谱中，高频峰值间距为 BPFO。

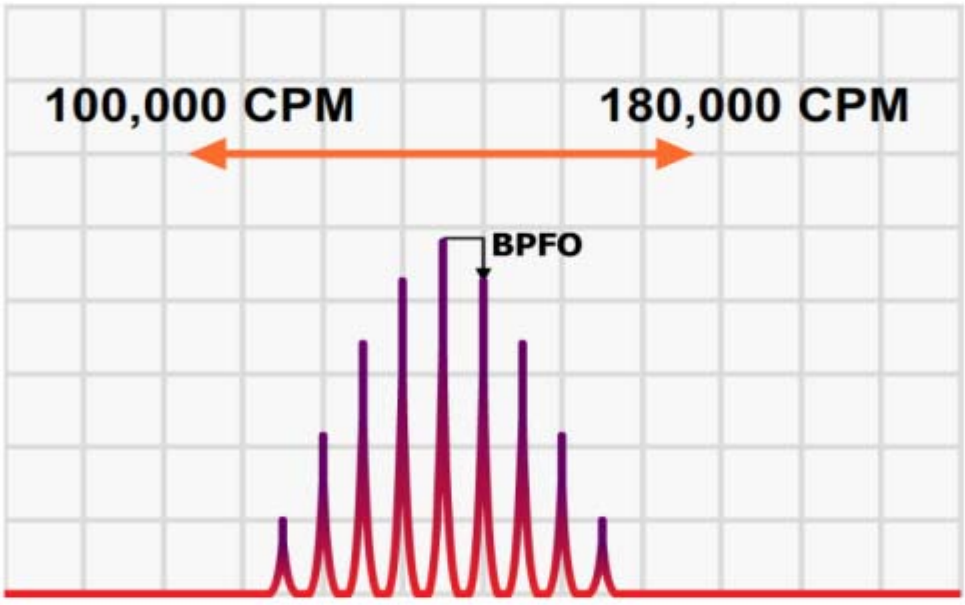
这种故障在直流电机和有 VFD 变频器的设备上很常见。

频谱：在高频约 1600 Hz to 3000 Hz 处，会看到一系列峰值升起。峰值间间隙通常为 BPFO（轴承外滚道故障频率）。大家认为，该振动激起了共振。

时域波形：会显示故障，但是频谱是最有效的工具。

HFD：取决于滤波设置。高频技术会显示轴承正在发出高幅值的高频振动。





3.10 Rolling element bearings: Rolling elements skidding 滚动轴承：滚子打滑

Symptoms: Elevated noise floor plus BPFO or BPFI peaks protruding above noise floor 特征：在抬起的底部噪声上会有 BPFO 或 BPFI 峰值

If a bearing is correctly selected for its application, and the lubricant is functioning

如果轴承选型正确，润滑剂正常工作。

correctly, and there is adequate load on the rolling elements, then the rolling elements should continuously roll around the raceways. However it is not uncommon for the rolling elements to slide or skid from time to time when these conditions are not met. This is more common on non-drive-end bearings, especially on vertical machines, and far more common with cylindrical roller bearings (as against deep groove ball bearings).

滚子负载足够，那么滚子会绕滚道连续运转。但是当条件不满足时，滚子偶尔打滑很常见。非驱动端轴承很常见，特别是在立式设备上，相比深沟球轴承，圆柱滚子轴承更常见。

You may hear the skidding occurring in the bearing, and you should look in the spectrum for an area of elevation, typically between 100 kCPM and 180 kCPM. Peaks of BPFO or BPFO may also be amplified in this region.

当轴承打滑时，你可能会听到。检查 1600 Hz to 3000 区域的幅值高度。在此区域，BPFO 或 BPFI 可能会被放大。

Spectra: Look for the raised noise floor in the region of 100-180 kCPM with BPFO or BPFI peaks protruding above the "hump".

频谱：检查 1600 Hz to 3000 区域抬起的底部噪声，在“驼峰”上有 BPFO 或 BPFI 突起。

Tip: Give the bearing a shot of grease to see if that makes a difference. Listen for the skidding sound – it may be intermittent. You may observe a difference if the temperature of the bearing varies (due to environment or operational changes) as the viscosity of the lubricant may change.

建议：给轴承加点润滑油，看是否有变化。监听打滑的声音，可能是间歇性的。如果轴承温度发生变化，润滑脂的粘度会改变（由于环境或操作条件），监听到的情况会有差别。

Waveform: Look for signs of skidding.

时域波形：查看打滑的征兆。

IR: You may be able to detect a temperature change with a spot radiometer or IR camera.

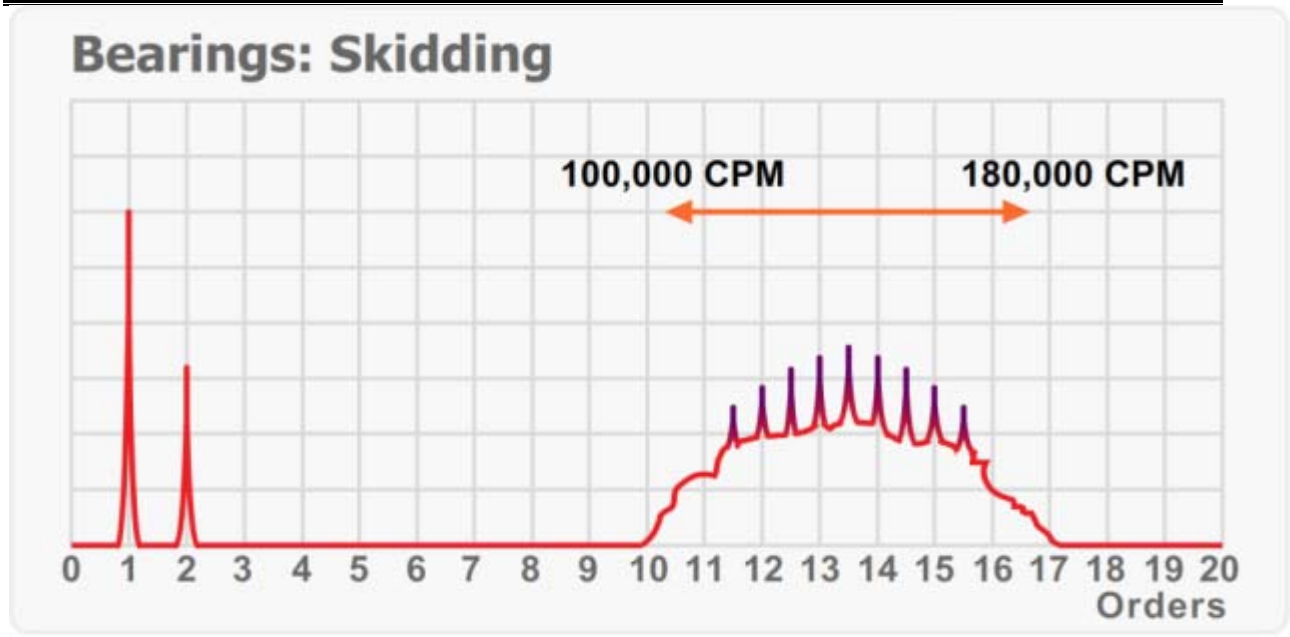
IR：使用红外或测温枪可以检测到温度变化。

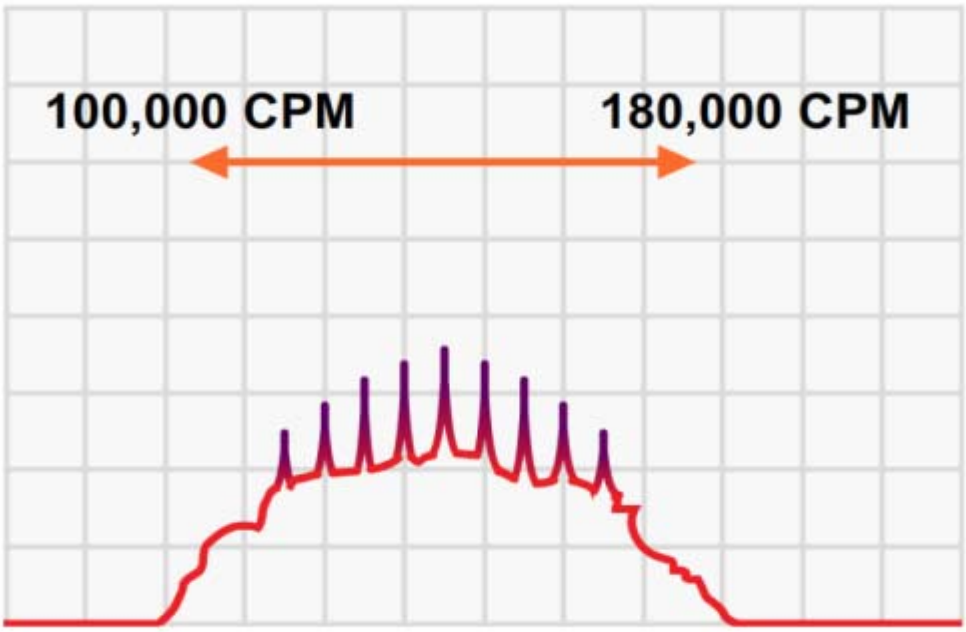
HFD: Depending upon your filter settings, the HFD techniques should indicate that the bearing is emitting a higher level of high frequency vibration.

HFD：取决于滤波设置。高频技术会显示轴承正在发出高幅值的高频振动。

Visual: When you replace the bearing, look at the surfaces for tell-tale signs of skidding.

肉眼：当你更换轴承时，查看滚子表面，可以看到打滑的迹象。





3.11 Rolling element bearings: Inner race sliding on shaft 滚动轴承：跑内圈

Symptoms: Raised 3X peak with harmonics 特征：3X 峰值及谐频

If the bearing is not installed correctly, the inner race may slide on the shaft – i.e. not

如果轴承安装不正确，轴承内圈可能跑

always turn at the same speed as the shaft. Depending upon the nature of the sliding, the vibration spectrum may have an elevated 3X peak and there may be harmonics of the 3X frequency. If the sliding motion is intermittent, i.e. it slides a little then stops, slides a little then stops, then you may not observe the change in the spectrum. However if it is constantly sliding then the vibration pattern should change accordingly.

套-即内圈和转轴之间的速度不是总相同。根据跑套的性质，振动频谱中会有3X 峰值及谐频。如果跑套是间歇性的，也就是说，跑了一点，然后停止，又跑一点，然后停止，那么在频谱中看不到该变化。但是如果一直跑套，那么振动模式会相应的改变。

Spectra: Look for the high 3X peak and harmonics (6X, 9X, etc.).

频谱：查找 3X 峰值及谐频（6X, 9X,等）

Visual or strobe: If it is possible to view the bearing in the machine (by removing a cover if necessary), you can use a strobe synchronized to the shaft speed to see whether the inner race is consistently turning at the same rate as the shaft. If the machine can be stopped then you may add a mark on the shaft and the inner race to determine whether there is relative motion.

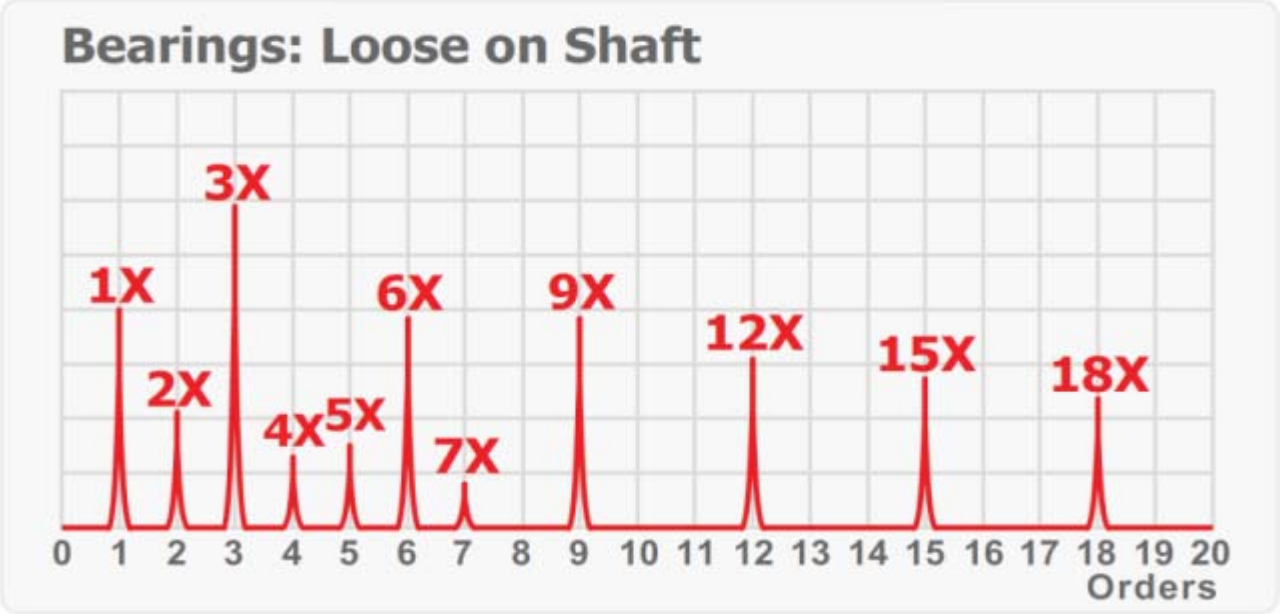
肉眼或频闪仪：如果可能查看到设备里的轴承（如果必要，拆开轴承盖），频闪仪同步到转轴速度，确认内圈和转轴速度是否一直相同。如果设备可以停机，那么在转轴和内圈上做个标记，确认是否有相对运动。

Waveform: Time waveform analysis can be used to detect the condition, especially if the movement is intermittent.

时域波形：时域波形可以检测该故障，特别是运动是间隙性的。

When you remove the bearing check the shaft and the inside of the inner race for tell-tale signs of sliding.

当你拆开轴承，检查转轴和内圈。能看到松动的迹象。



3.12 Rolling element bearings: Outer race loose in housing 滚动轴承：跑外圈

Symptoms: Elevated 4X peak 特征：4X 峰值升高

If the bearing is not installed correctly within the housing, the outer race may move relative to the housing; it may begin to spin

如果在安装轴承时，外圈和轴承箱的配合间隙不当，那么外圈可相对于轴承箱

and even "rattle" within the housing. The peaks at 4X running speed may be elevated when this occurs.

If it is possible to view the bearing within the machine (by removing a cover if necessary), you will be able to see if the outer race is moving relative to the bearing housing. If the machine can be stopped then you may add a mark on the housing and the outer race to determine whether there is relative motion.

Time waveform analysis will also indicate if the outer race is loose in the housing.

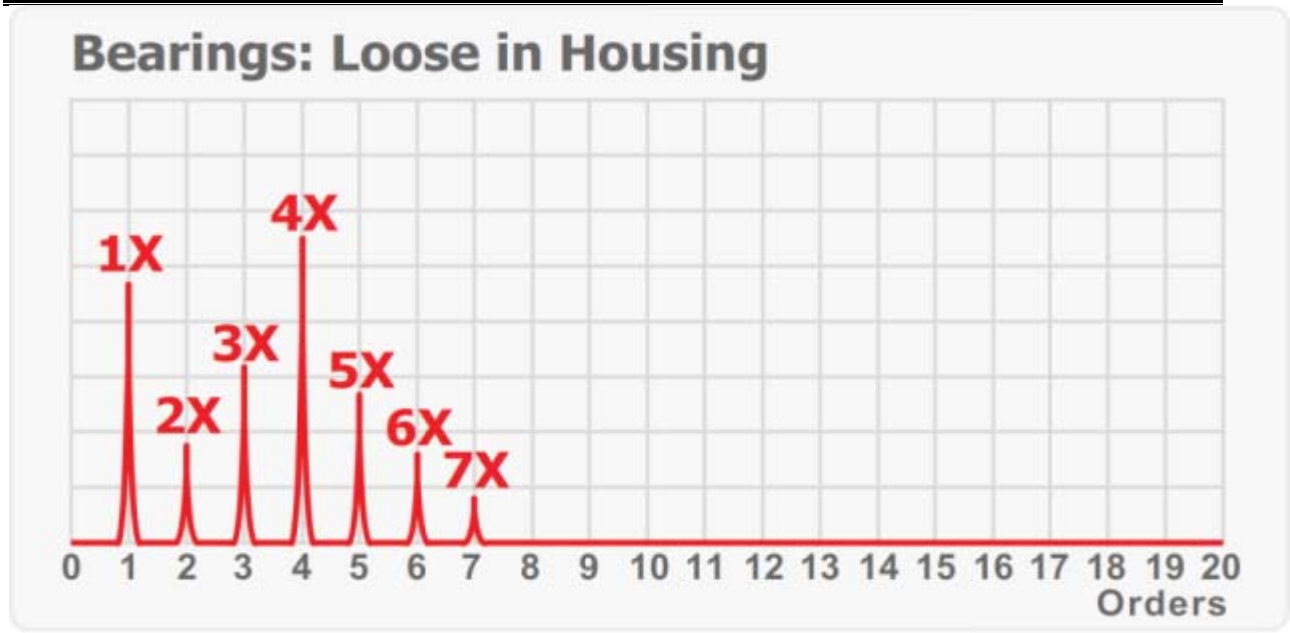
When the bearing is removed, the outside of the outer race should be observed for tell-tale signs of looseness.

运动。在轴承箱内，它可能会开始旋转，甚至发生短促尖厉“咔嗒”撞击。当这种情况发生时，4X 峰值可能会升高。

如果可能查看到设备里的轴承（如果必要，拆开轴承盖），你会看到轴承外圈和轴承箱是否发生相对运动，确认内圈和转轴速度是否一直相同。如果设备可以停机，那么在轴承箱和外圈上做个标记，确认是否有相对运动。

时域波形分析也能指示轴承外圈是否跑套

当查看轴承，查看外圈，能看到松动的迹象。



4 Analysis Definitions: Looseness 松动

Symptoms: Rotating: 1X harmonics / Structural: 1X horizontal / Pedestal bearing: 1X, 2X, and 3X vertical 特征：旋转部件：1X 谐频/结构：1X 水平/轴承座：1X、2X、3X 垂直

Rotating looseness is caused by excessive clearance between rotating and stationary elements of the machine such as in a bearing, while non-rotating looseness is a looseness between two normally stationary parts, such as a foot and a foundation, or a bearing housing and a machine.

旋转部件松动是设备的转动和静止部件间隙过大造成的，如轴承。而非旋转松动是两个静止部件发生松动，如地脚和底座或轴承箱和设备之间。

Structural looseness, or looseness between a machine and its foundation, will increase the 1X vibration component in the direction of least stiffness. This is usually the horizontal direction, but it depends on the physical layout of the machine.

结构松动，或设备地脚松动，在刚度变小的方向上 1X 振动会变大。常常是水平方向，这跟设备的安装布局有关。

Spectrum: Each type of looseness has its own special characteristic. Rotating looseness will generate a large number of harmonics and may cause the noise floor to rise. Structural looseness will not cause harmonics unless there is impacting – simple "weakness" or "flexibility" will generate high amplitude 1X peaks in the direction of least stiffness.

频谱：每种类型的松动都有自己的特性。旋转部件松动会产生大量的谐频，并可能导致底部噪声抬起。结构松动不会产生谐频，除非有冲击-刚度最小的方向上 1X 振动会最大。

Phase: Phase can be a very useful tool. Rotating looseness generates "random" vibration, so the phase is erratic. Structural looseness will often have one component vibrating (the foot of the motor) and one stationary (the foundation) – you can therefore look for a 180° phase difference between the stationary and vibrating component.

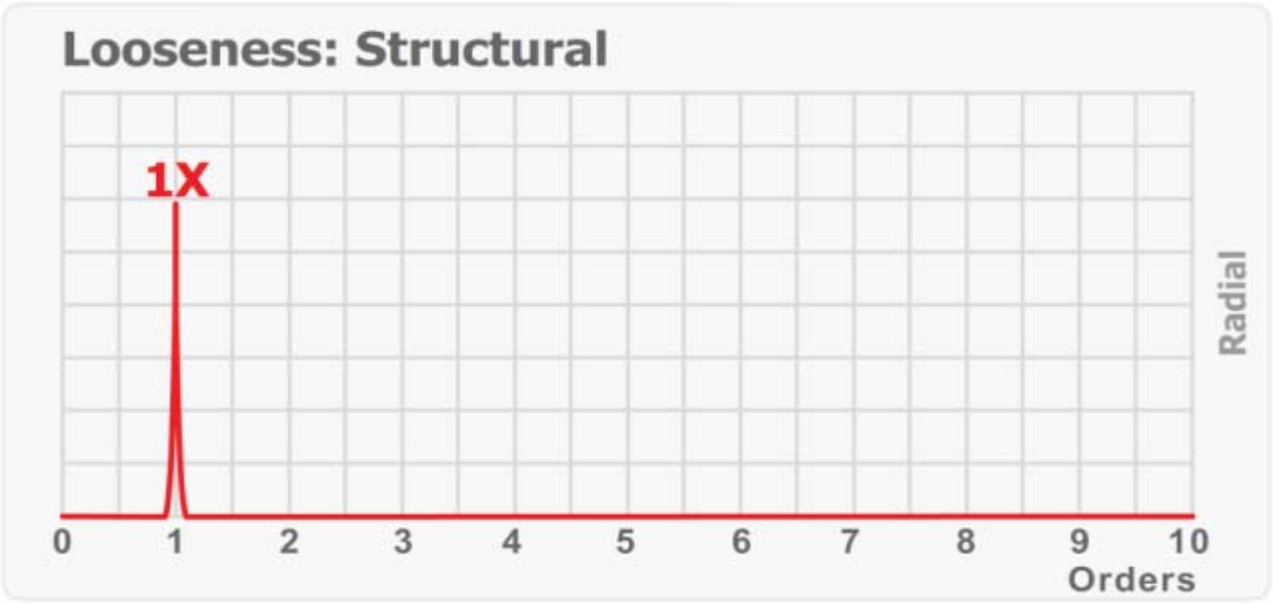
相位：相位是很有用的工具。旋转部件松动会产生“随机”振动，所以相位是不稳定的。结构松动往往是一个部件振动（电机地脚），另一个静止（底座）。所以你能看到静止和振动部件的相位差是 180°。

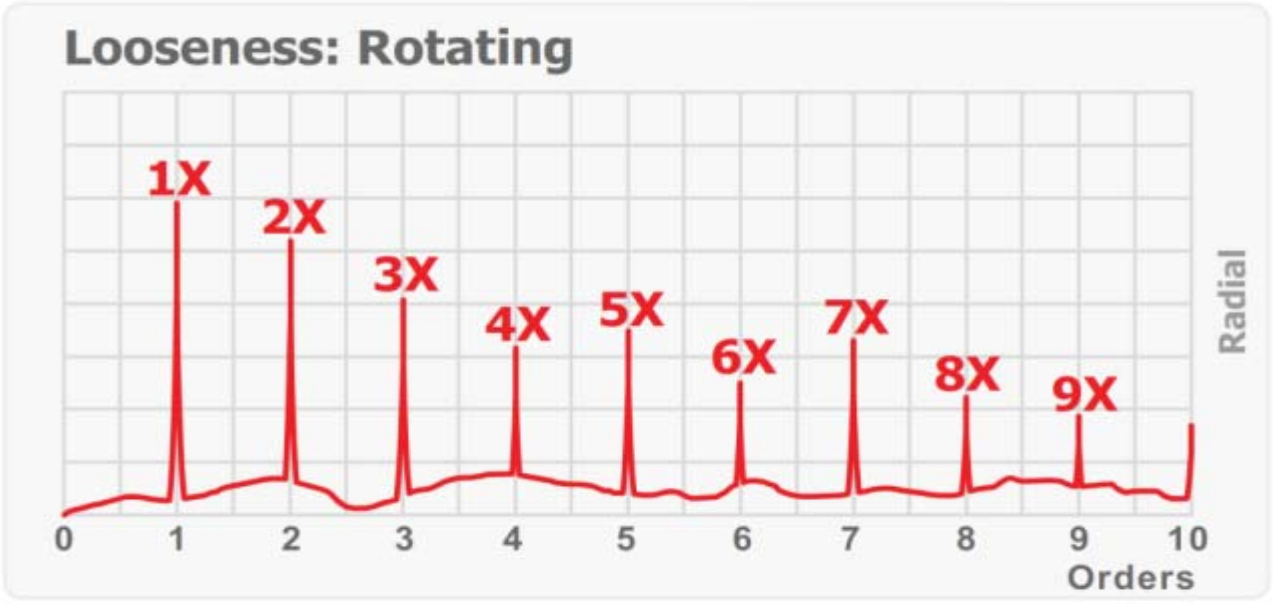
Waveform: The time waveform is also useful. Impacting is quite obvious, especially when viewed in acceleration, whereas structural looseness will be more sinusoidal.

时域波形：时域波形也是很有用。尤其在采用加速度单位时，冲击更明显。而结构松动会是正旋波。

HFD: Impacting will generate stress waves and excite natural frequencies in the bands used by demod/enveloping/PeakVue, etc.

HFD:冲击会产生某频段内的压力波和激发共振频率，可以使用解调/包络/PeakVue 等。





4.1 Looseness: Rotating looseness 松动：旋转部件

Symptoms: 1X harmonics radial (0.5X harmonics when severe)特征：1X 谐频径向（严重时 0.5X）

Excessive clearance in journal (sleeve) and rolling element bearings will produce harmonics of 1X turning speed that can

当滑动轴承和滚动轴承间隙过大时，会产生 1X 谐频，某些情况下，可产生

extend, in some cases, above 10X. Impacting can cause the noise floor to rise.

Looseness in rolling element bearings can occur after significant bearing wear and may be observed during Stage four of the bearing fault.

Excessive journal bearing clearance can produce harmonics of 0.5X. They are called half order components or sub harmonics. They can be produced by rubs and severe impacting. Even 1/3 order harmonics are possible.

Spectrum: Rotating looseness will generate a large number of harmonics and may cause the noise floor to rise.

Phase: Rotating looseness generates "random" vibration, so the phase is erratic. It is important to view the phase reading "live" so you can see if the phase reading (relative to the tachometer or relative to another point on the machine) is steady.

Waveform: Impacting is quite obvious in the time waveform. It is best to use units of acceleration (g's or mm/sec^2).

HFD: Impacting will generate stress waves and excite natural frequencies in the bands used by demod/enveloping/PeakVue, etc. Therefore you should expect to see harmonics of 1X turning speed in your demod/envelope/PeakVue etc. spectrum.

10X。冲击能导致底部噪声抬起。

在滚动轴承严重磨损后和在第四阶段故障中会发生松动。

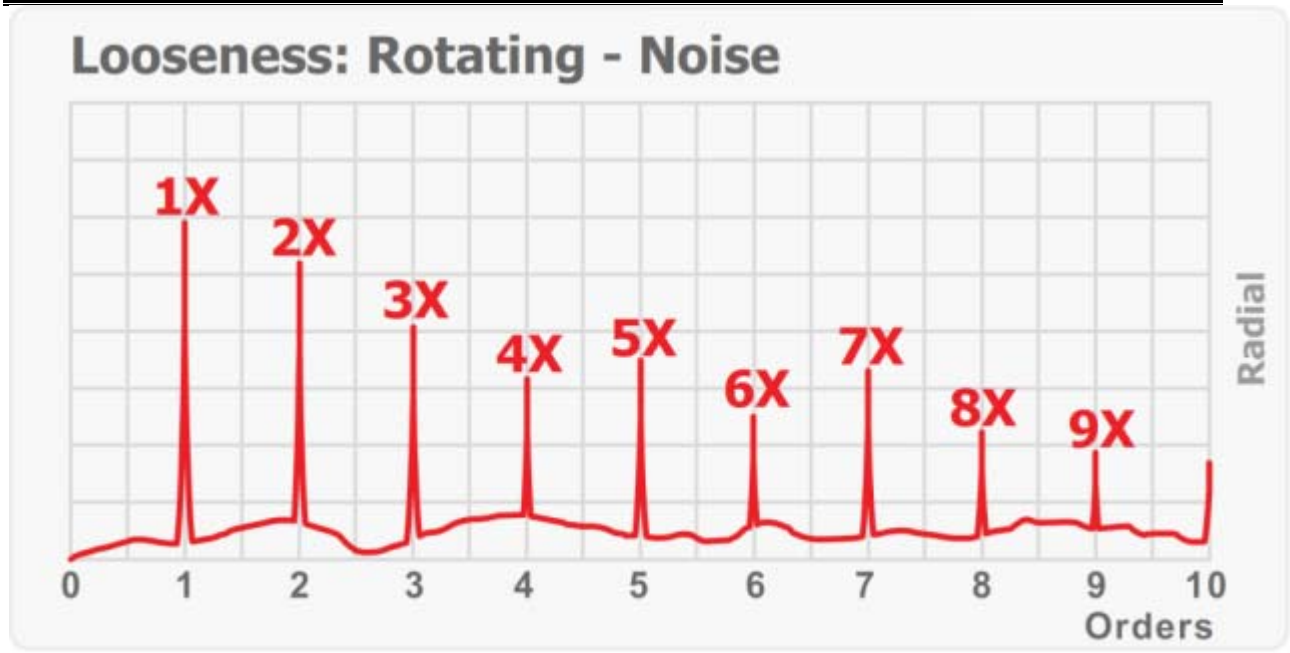
滑动轴承间隙过大会产生 0.5X。也称半频或亚倍频。这是由摩擦和严重的冲击产生的，甚至可能产生 0.3X。

频谱：旋转部件松动会产生大量谐频和抬起的底部噪声。

相位：旋转部件松动会“随机”振动，所以相位是不稳定的。实时相位读数是否稳定很重要的（转速传感器相对于键槽）。

时域波形：时域波形中冲击很明显，最好使用加速度单位。（g's 或 mm/sec^2）

HFD: 冲击会产生某频段内的压力波和激发共振频率，可以使用解调/包络/PeakVue 等。所以会在解调谱中看到 1X 谐频。



4.2 Looseness: Structural looseness 松动：结构松动

Symptoms: Structural: 1X horizontal 特征：结构：1X 水平

This form of looseness is caused by weakness in foundations (e.g. failed grout or cracks in concrete bases), cracks or other

这种形式的松动是由基础刚度变弱（水泥灌浆失效或混凝土裂纹），设备安装支

forms of weakness in machinery mounts, base plates, hold down bolts, etc. This weakness allows the machine to vibrate more freely in the direction where the weakness is greatest (often horizontal), therefore the vibration at turning speed will be elevated.

架，底座，螺栓连接造成的。刚度变小（通常是水平）的地方，设备可以更自由的振动，所以 1X 转频幅值会升高。

Unbalance, structural looseness and resonance can easily be confused. See the "Additional tests" page to learn how to differentiate them.

不平衡、结构松动和共振很容易混淆。查看“Additional tests”进行区分。

Foundation flexibility or looseness can be caused by loose bolts, corrosion, or cracking of mounting hardware. Note: If a machine has resilient mounts, then the vibration will always be greater in the horizontal axis.

松动的螺栓、腐蚀、开裂的支架，可以导致基础变的弹性或松动。注意：如果设备是弹性基础，那么水平方向振动总是会大。

Spectrum: Structural looseness will generate a strong 1X in the direction ofgreatest weakness – unless there is impacting, in which case there will also be harmonics. To distinguish looseness/unbalance/resonance: If 1X horizontal more than twice the amplitude of 1X vertical, looseness is suspected. If that amplitude ratio changes when the machine speed is changed then resonance should be suspected.

频谱：结构松动会在刚度变小的方向产生很大 1X 的幅值-除非有冲击，这种情况下也会产生谐频。

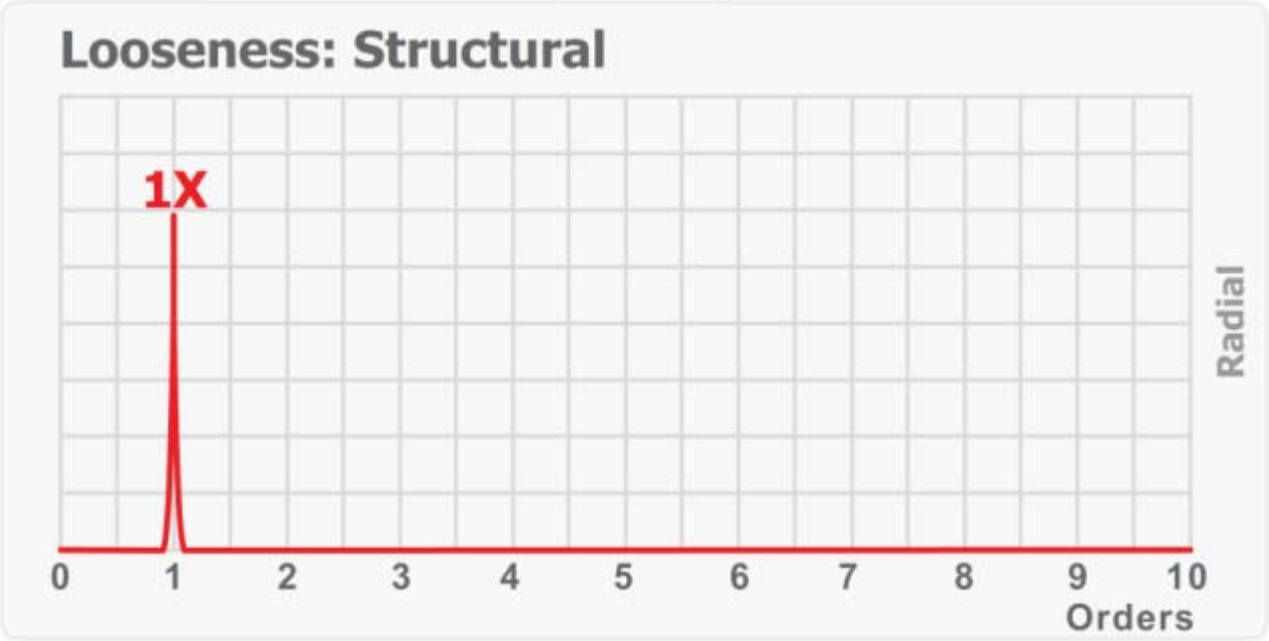
对松动/不平衡/共振进行区分：如果 1X 水平幅值>2 倍垂直，可怀疑是松动。如果当转速变化时，幅值变化比例发生改变了，可能是共振。

Phase: Structural looseness will often have one component vibrating (the foot of the motor) and one stationary (the foundation) – therefore look for a 180° phase difference between the stationary and vibrating component.

相位：结构松动往往是一个部件振动（电机地脚），另一个静止（底座）。所以你能看到静止和振动部件的相位差是 180°。

Waveform: The waveform will be quite sinusoidal (in velocity). If there is any contact, the top and/or bottom of the wave may be truncated.

时域波形：时域波形是正旋波（速度单位）。如果有任何接触，波形的顶部或底部会发生削波。



4.3 Looseness: Loose pedestal bearings 松动：轴承座松动

Symptoms: 1X, 2X, and 3X radial 特征：1X、2X、3X 径向

This is a unique form of looseness caused by cracks in the bearing pedestals, loose pedestal (pillow block) bolts, or faulty

有裂纹的轴承座、松动的轴承座，故障隔离器，会造成这种独特形式的松动。

isolators. The vibration will have a strong 1X and 2X component due to the motion generated by the machine. The 2X peak may be higher than the 1X peak which may lead you to suspect misalignment. In some cases a 3X frequency will be generated, as will fractional-frequency vibration (1/2X, 1/3X, 1/4X, etc.).

由于设备发生的运动，会产生很大 1X，2X 幅值。由于 2X 幅值可能比 1X 幅值大，常常被怀疑为不对中。某些情况下，会产生 3X，还有亚倍频振动（1/2X, 1/3X, 1/4X 等）。

The spectrum will have components at 1X, 2X and 3X (but often no more harmonics), with a 0.5X peak in more severe cases.

频谱中会有 1X、2X 和 3X（但往往没有谐频），严重时会有 0.5X。

Phase can again be used to verify this condition as it will be erratic.

相位时不稳定的。

Spectrum: Look for 1X and high 2X peaks. 3X, and sub-harmonics (1/2X, 1/3X, 1/4X, etc.) peaks may also be present.

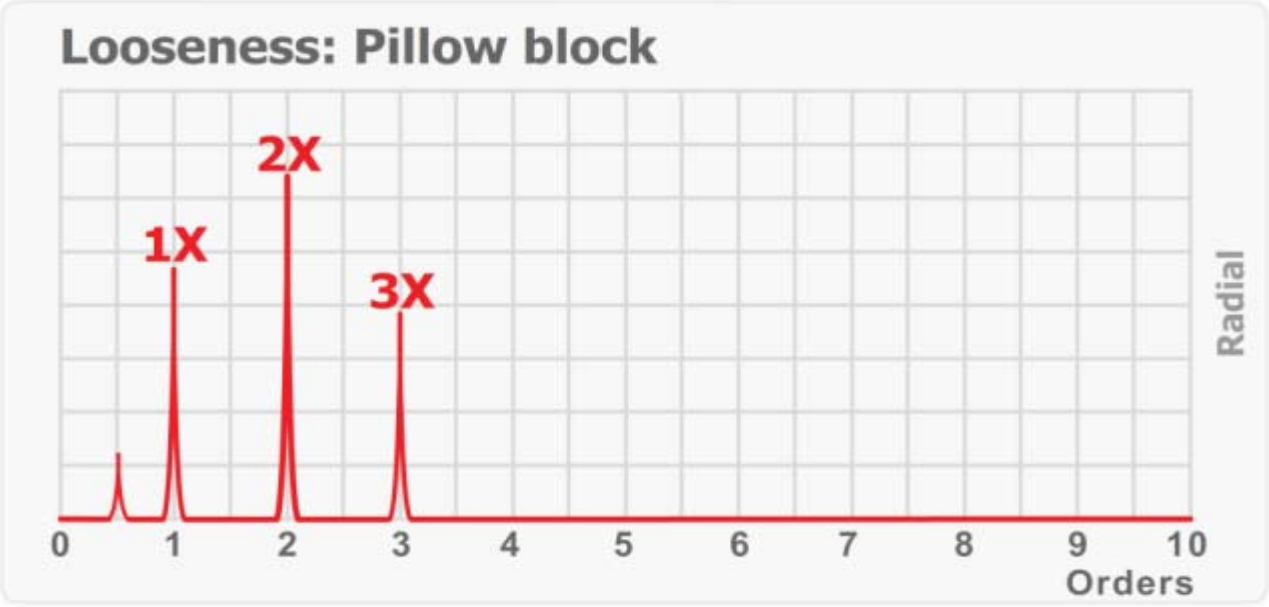
频谱：查看 1X 和高幅值的 2X 还有 3X，亚倍频（1/2X, 1/3X, 1/4X 等）可能会出现。

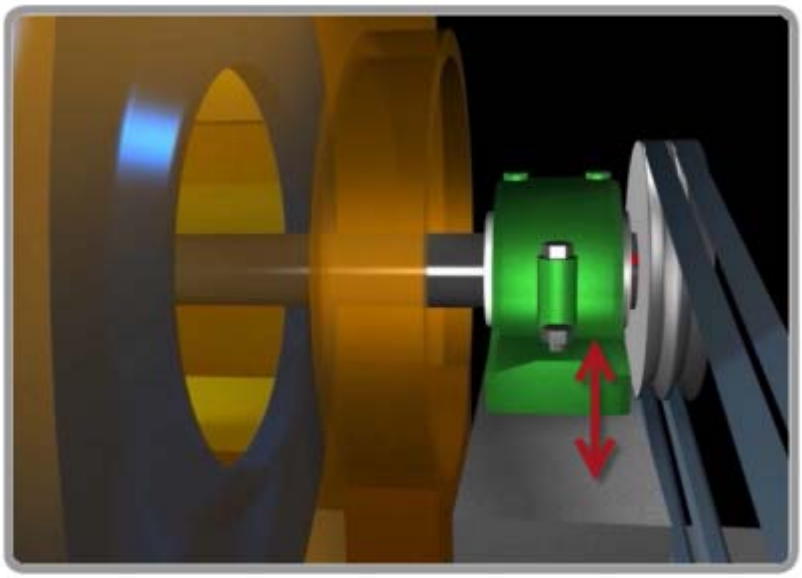
Phase: Phase will not be consistent due to the vibration motion generated (as opposed to misalignment which will generate a steady phase relationship).

相位：由于运动方式，相位不会一直稳定（而不对中会产生稳定的相位）。

Waveform: Due to the motion generated, the waveform will show that the vibration is not constant from cycle to cycle. This is most easily observed in units of velocity and when you can see 10-15 cycles of rotation.

时域波形：由于运动方式，时域波形不会是恒定的循环周期。采集 10-15 个周期，并使用速度单位，更容易查看。





5 Analysis Definitions: Resonance 共振

Symptoms: "Hump" or high peak in spectrum typically in one direction only 特征：“驼峰”或一般只在一个方向的频谱上有高的峰值

Resonance is very common in machines, and the structures supporting machines.

共振在设备和设备支撑结构中很常见。

Resonances amplify vibration at the natural frequency and ~15% either side.

共振会放大固有频率±15%内的振动。

If the natural frequency is close to the turning speed of the machine, the amplitude at 1X will be high, and the area around the base of the 1X peak will be amplified. Unbalance, misalignment and other conditions will further amplify the vibration. Natural frequencies at other frequencies may be amplified by pump-vane rate, bearing wear and other conditions. Resonances increase vibration levels and reduce machine life.

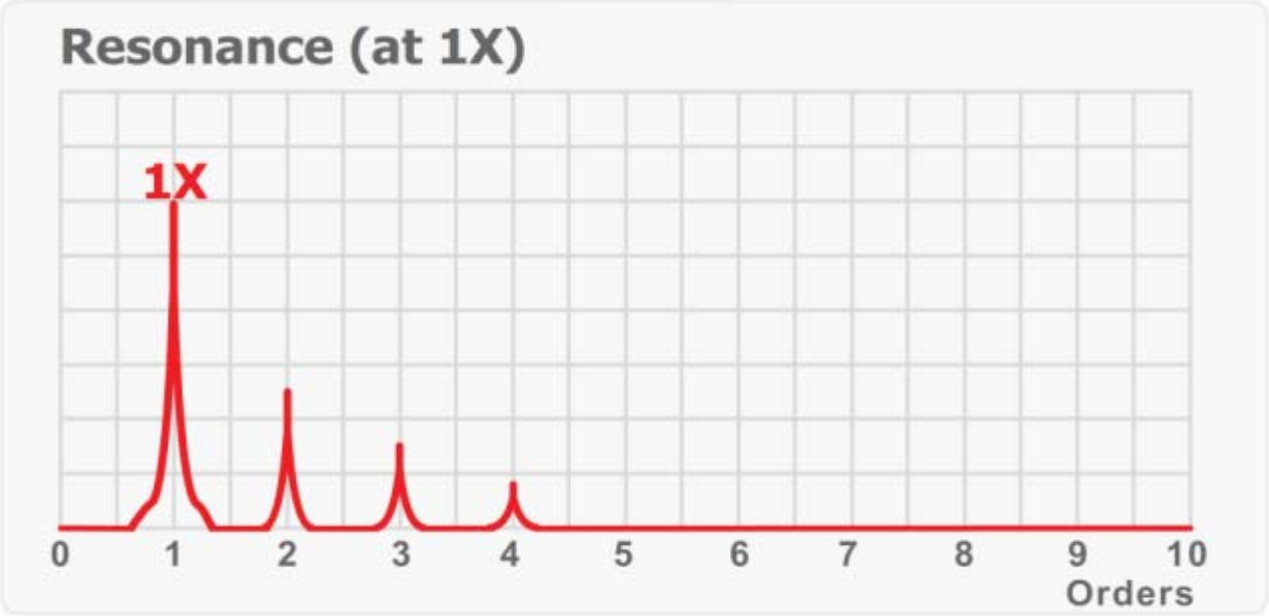
如果固有频率接近设备的转频，那么 1X 幅值会很高，1X 附近频率的底部会被放大。不平衡、不对中和其它故障会进一步放大振动。其它的频率的固有频率会被叶片通过频率、轴承磨损和其它故障放大。共振会增加振值，减少设备寿命。

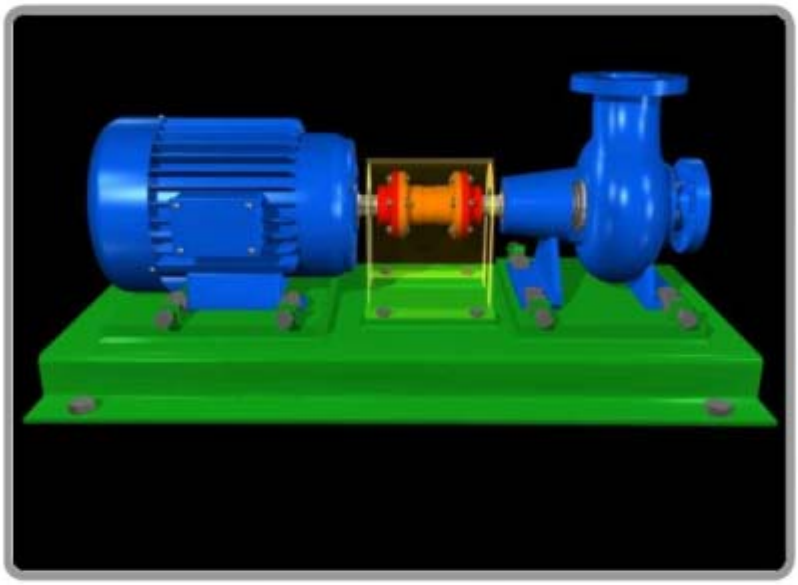
Spectrum: Strong peak at natural frequency. The base of the peak will also be elevated. Machine and process noise can excite a natural frequency causing large "humps" to appear in the spectrum.

频谱：固有频率上有大的峰值，峰值的底部也会被抬高。设备和工艺的噪声可以激发固有频率，导致频谱中出现大的“驼峰”。

Additional tests: A variety of tests exist. If you vary the machine speed, the vibration amplitude will change if it moves closer (increase) or further away (decrease) from the natural frequency. If you monitor the phase at the frequency exciting the natural frequency you will see a 180° phase shift. Bump tests can indicate the frequency of natural frequencies. Many other tests exist: modal analysis, Bodé tests, ODS, and more.

辅助测试：存在各种测试。如果设备可以变速，那么振动幅值会变化，接近固有频率时（增长）或远离时（减少）。如果监测相位，会发现 180°变化。敲击测试可以指示固有频率。还有其它测试方法：模态分析，伯德图，工作变形分析等。





5.1 Resonance: Excited by fluting/EDM 共振：轴电流激起

Symptoms: Series of peaks commonly between 100k CPM and 180k CPM100k CPM-180k CPM 之间会有一系列常见峰值

If the machine generates high frequency vibration the any natural frequencies are

如果设备产生高频振动，任何固有频率可能被激起。

likely to be excited. It is not uncommon for there to be a natural frequency in the range of 100,000 CPM (1650 Hz) and 180,000 CPM (3000 Hz) which will be excited when there is fluting (EDM) due to current passing through rolling element bearings or when the rolling elements skidding between the races. In both cases you will see the noise floor lift up with peaks protruding at (typically) the BPFO or BPFI bearing defect frequencies.

当有轴电流（EDM）或滚子打滑时，1650 Hz-3000 Hz 范围的固有频率被激起很常见。这两种情况下，你可以看到在抬起的底部噪声行，有 BPFO 或 BPFI 峰值。

Please also see the section on fluting and skidding, but also consider cavitation and dirt ingress.

请参考轴电流和打滑部分，还有考虑气蚀和进入的灰尘。

Spectrum: Often there will be a series of peaks that will rise up at a high frequency, commonly between approximately 100,000 CPM and 180,000 CPM (1600 Hz to 3000 Hz). The peaks are commonly spaced by the outer race BPFO frequency (sometimes BPFI). It is believed that the vibration is exciting a resonance.

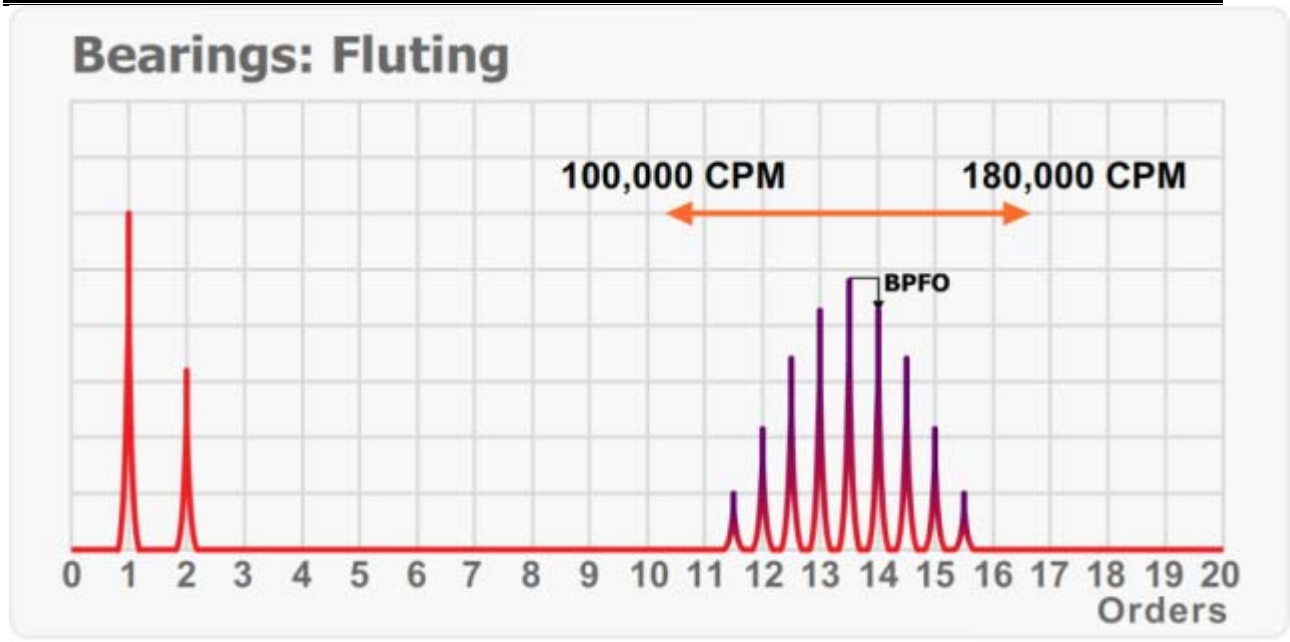
频谱：在高频约 1600 Hz to 3000 Hz 处，会看到一系列峰值升起。峰值间间隙通常为 BPFO（有时 BPFI）。大家认为，该振动激起了共振。

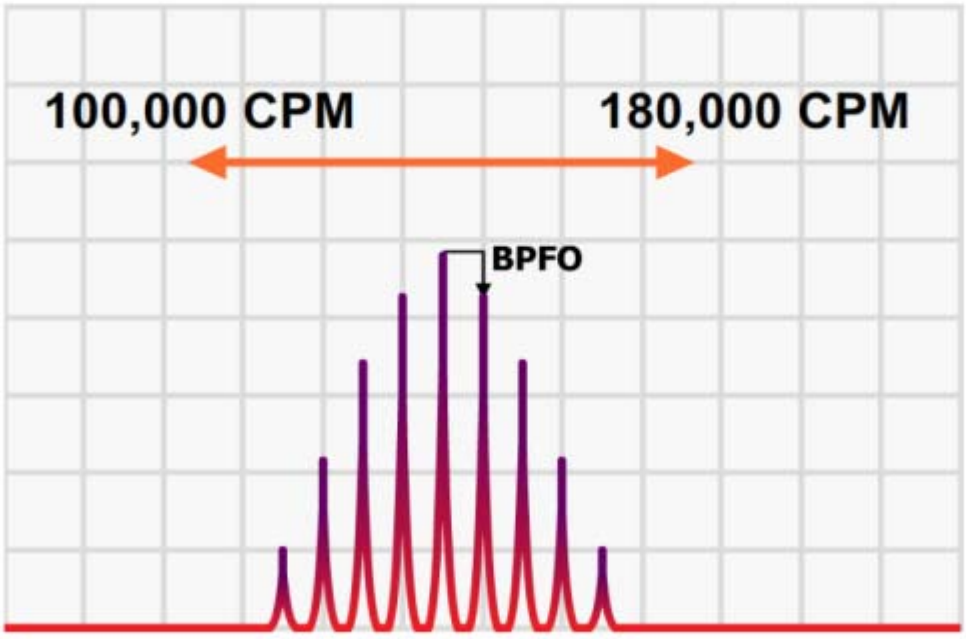
Waveform: The fault will be indicated, but the spectrum is the best tool.

时域波形：会显示故障，但是频谱是最有效的工具。

HFD: Depending upon your filter settings, the HFD techniques should indicate that the bearing is emitting a higher level of high frequency vibration.

HFD：取决于滤波设置。高频技术会显示轴承正在发出高幅值的高频振动。





5.2 Resonance: Excited by bearing skidding 共振：打滑激起

Spectrum: Often there will be a series of peaks that will rise up at a high frequency, commonly between approximately 100,000 CPM and 180,000 CPM (1600 Hz to 3000 Hz). The peaks are commonly spaced by the outer race BPFO frequency (sometimes

频谱：在高频约 1600 Hz to 3000 Hz 处，会看到一系列峰值升起。峰值间间隙通常为 BPFO（有时 BPFI）。

BPFI). It is believed that the vibration is exciting a resonance.

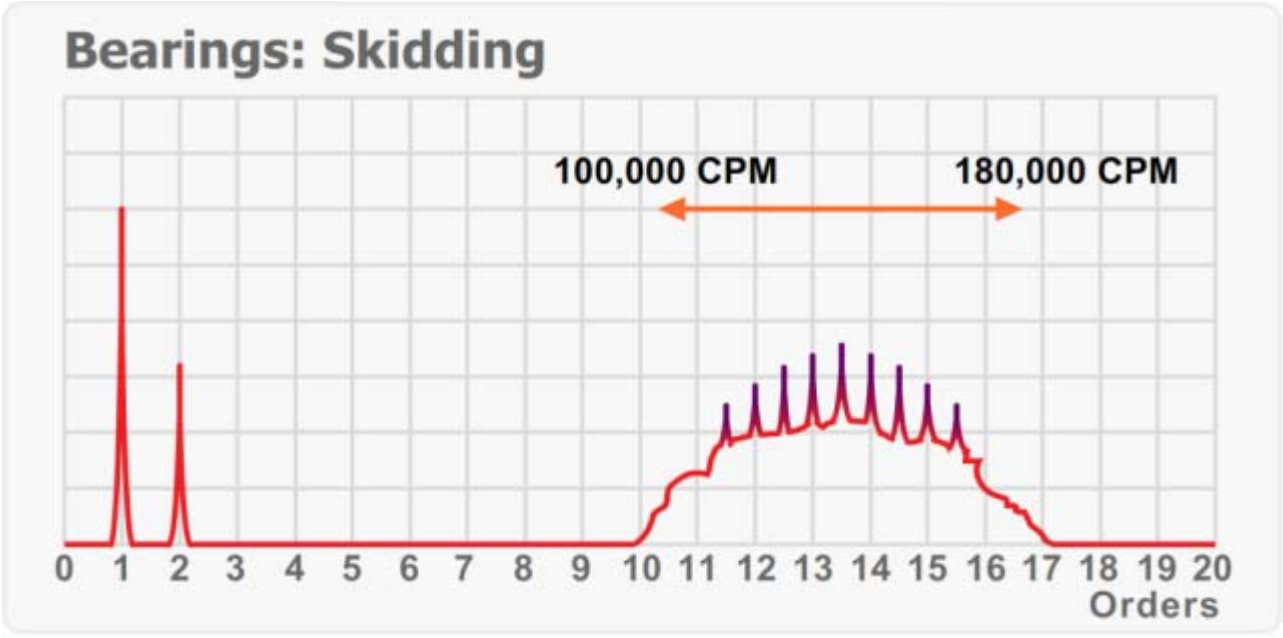
该振动激起了共振。

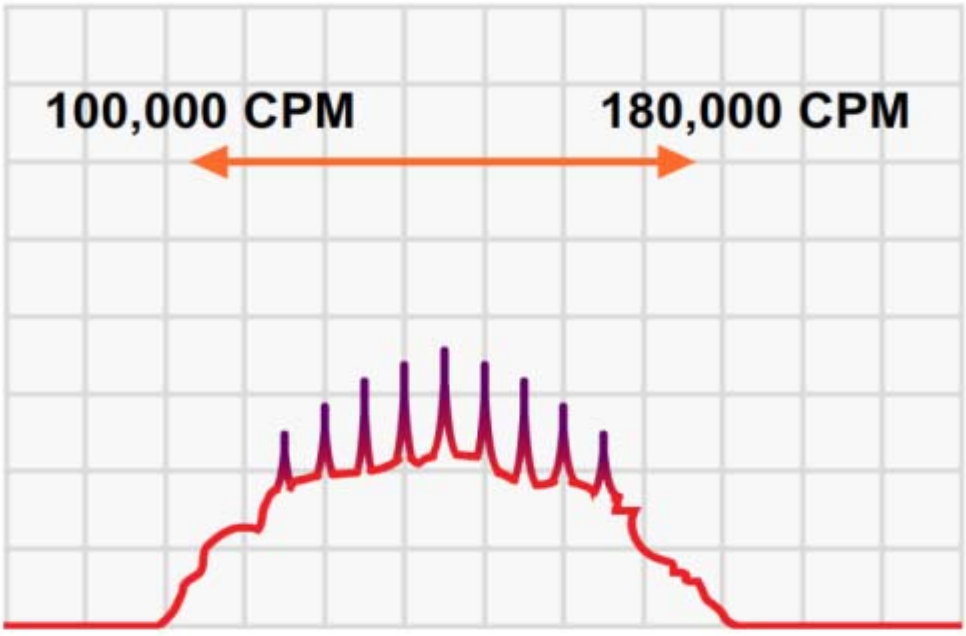
Waveform: The fault will be indicated, but the spectrum is the best tool.

时域波形：会显示故障，但是频谱是最有效的工具。

HFD: Depending upon your filter settings, the HFD techniques should indicate that the bearing is emitting a higher level of high frequency vibration.

HFD：取决于滤波设置。高频技术会显示轴承正在发出高幅值的高频振动。





6 Bent shaft: Bent Shaft 轴弯

Symptoms: 1X (and often 2X) axial 特征：1X（往往 2X）轴向

The shaft may bend due to excessive heat (see also shaft bow), due its length (catenary sag), or it may be physically bent. A bent shaft predominantly causes high 1X axial vibration. The dominant vibration is normally at 1X if the bend is near the center of the shaft, however you will see 2X vibration if the bend is closer to the coupling.

转轴可能由于温度过高（弓轴），长度（悬链线下垂）或物理变形，变弯曲。轴弯主要是 1X 轴向振动。如果弯曲接近转轴中心，主导振动时 1X。如果弯曲接近联轴器，你会看到 2X 振动。

Vertical and horizontal axis measurements will also often reveal peaks at 1X and 2X, however the key is the axial measurement.

垂直和水平方向的频谱中有会 1X、2X 峰值，但是关键是轴向数据。

Phase is also a good test used to diagnose a bent shaft. The phase at 1X measured in the axial directions at opposite ends of the component will be 180° out of phase.

相位用来诊断轴弯是很有用的。支撑转轴的轴承的 1X 轴向相位差 180°。

Spectrum: Look for a high 1X peak in axial. If the bend is close to the coupling then you will see a higher 2X peak. You may also observe higher than normal 1X and 2X peaks in the radial direction.

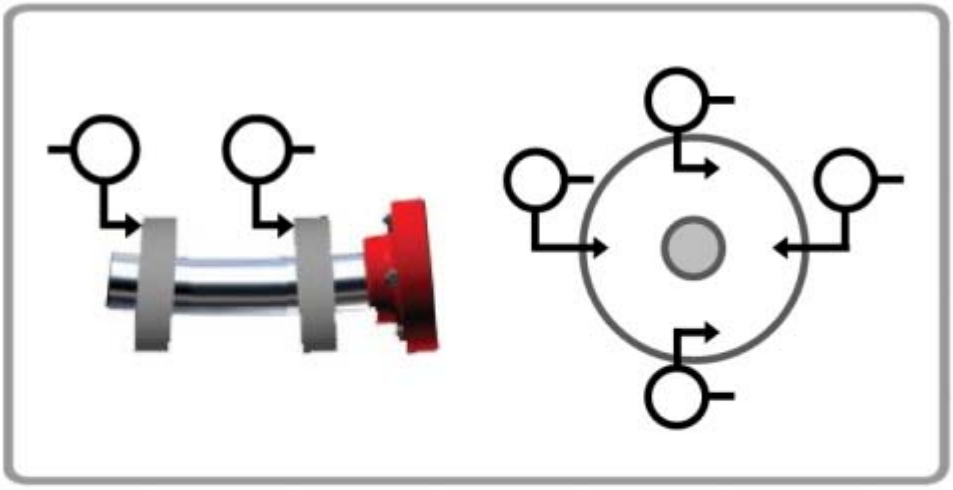
频谱：查看轴向 1X，如果弯曲接近联轴器，你会看到 2X 更高。你也会看到比径向 1X、2X 的峰值高。

Phase: Phase measurements taken axially on the bearings at each end of the shaft will be 180° out-of-phase. If phase readings are taken on the face of the component around the shaft you should find that they are all in-phase – the shaft will appear to be moving back and forth axially.

相位：支撑转轴的轴承轴向相位差 180°。同一轴承端面的轴向相位同相-转轴沿轴向来回运动。

Waveform: The time waveform is not the key indicator, however a sinusoidal waveform is expected in the axial direction if the vibration corresponds to 1X, or there will be a "wobble" (and possibly an "M" or "W" pattern depending upon the phase angle) if the bend is closer to the coupling.

时域波形：时域波形不是好的指标。如果轴向是 1X，时域波形是正旋波。或如果弯曲接近联轴器，会有抖动（"M" 或 "W"的形状取决于相位角）



7 Cavitation: Pump cavitation 气蚀：泵气蚀

Spectrum: Look for the pump around the PV peak and look for the noise floor to rise up in the higher frequencies. This is easier to see in an acceleration spectrum.

频谱：很容易在加速度谱中查看到叶片通过频率和高频抬起的底部噪声。

Waveform: Look for random bursts of energy. The waveform will need to cover 10 seconds or more as the bursts may be 1-3 seconds apart.

时域波形：查看随机脉冲的能量。当脉冲是 1-3s 间隔时，时域波形长度需要 10s 或更长。

Audible: If you listen to the vibration, it can often sound like gravel in the pump.

声音：如果你听振动，泵中往往有碎石声。

8 Journal bearings 滑动轴承

8.1 Journal bearings: Wear/Clearance 滑动轴承：磨损/间隙

Symptoms: 1X harmonics 特征 1X 谐频

When there are clearance problems in sleeve (journal) bearings, you should observe a harmonic series with a fundamental frequency of turning speed. The forces will generate noise which can excite natural frequencies (resonance), therefore the noise floor may be raised.

当滑动轴承的间隙过大时，你应该看到 1X 转频及谐频。激振力会产生噪声可以激起固有频率（共振），因此底部噪声会抬起。

In more severe cases, half-order and even one-third order harmonics will be present in the spectrum.

在更严重的情况下，频谱中会出现 0.5X 和 0.3X。

Spectrum: 1X and harmonics. Noise floor may lift. Half-order and one-third order harmonics may also be present.

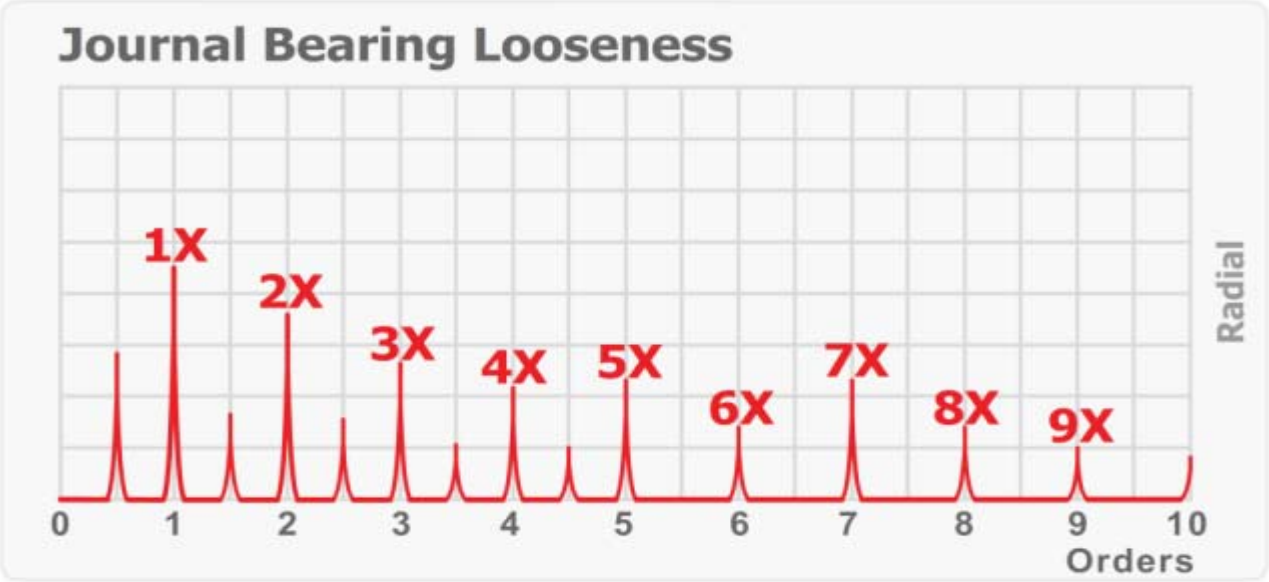
频谱：1X 及谐频，底部噪声抬起。0.5X 和 0.3X 也会存在。

Waveform: The time waveform would indicate that there was excessive clearance.

时域波形：时域波形会显示轴承间隙过大。

Orbit: If you are using data from displacement probes (e.g. proximity probes), make sure that you are not looking at filtered data when you view the spectrum or waveform.

轴心轨迹：使用电涡流位移传感器，查看频谱和波形时，确保不是滤波之后的数据。



8.2 Journal bearings: Oil whirl 滑动轴承：油膜涡动

Symptoms: 0.38-0.48X in radial 特征：0.38-0.48X 径向

Oil Whirl is a condition in which a strong vibration occurs at between 0.38X and 0.48X. It never shows up at precisely 0.5X, but is always a little lower in frequency.

It is caused by excessive clearance and light radial loading, which results in the oil

当在 0.38X-0.48X 之间发生强烈振动的一种状态就是油膜涡动。它永远不会是精确的 0.5X，总是比这个频率低点。

由于间隙过大和径向载荷较低，导致

film building up and forcing the journal to migrate around in the bearing at less than one-half RPM.

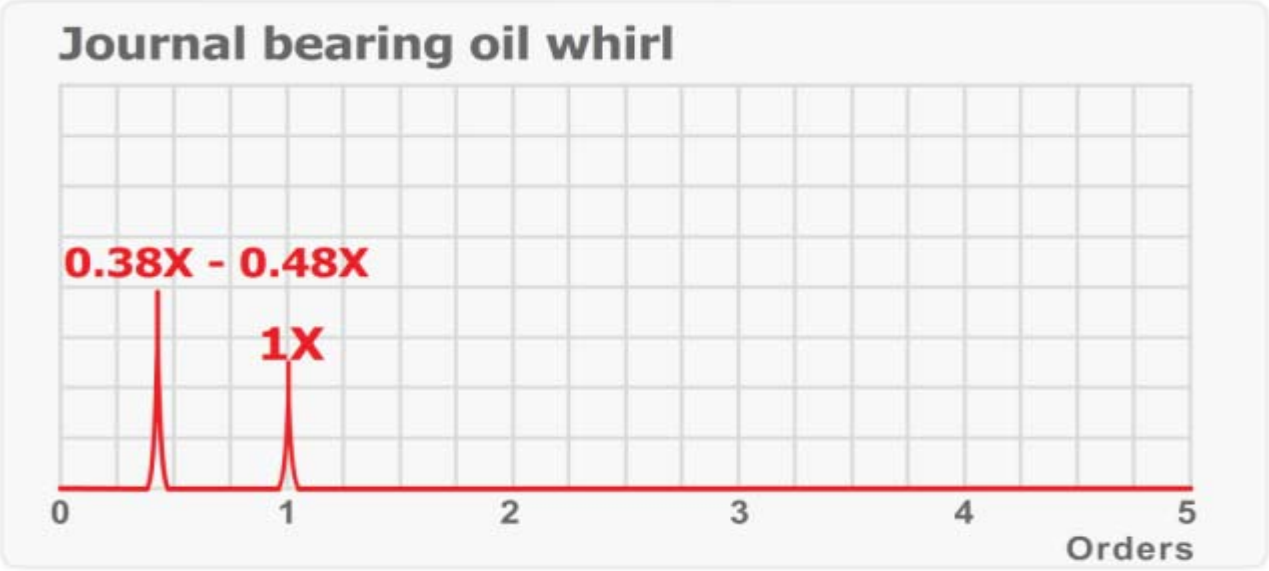
Spectrum: Strong peak at between 0.38X and 0.48X. The amplitude can be quite high.

Orbit: Because of the strong sub-synchronous vibration there will be two dots on the Orbit: and there may be an internal loop. Watching a live Orbit: will show that the inner-loop will rotate around the Orbit: in the direction of rotation.

油膜建立并使转轴旋转，涡动速度低于0.5X。

频谱：0.38X-0.48X 之间会有峰值，并幅值很高。

轴心轨迹：由于是很强的亚同步振动，轴心轨迹上会有两个点，轴心轨迹为大圈套小圈。



9 Analysis Definitions: Rotor rub 转子摩擦

Symptoms: 1X harmonics radial (0.5X harmonics when severe)特征 1X 谐频径向（严重时 0.5X 谐频）

When shafts or other rotating components come into contact with stationary components the vibration will change in characteristic ways. It is quite likely that the rotating part comes into contact once during each cycle of rotation, that is, it may not be in contact with the stationary component the entire time. Therefore the waveform may look 'normal' except when contact is made.

当转轴或其它旋转部件接触到静止部件时，振动特性会改变。很可能是，一个旋转周期内，旋转部件摩擦一次，也可能不与静止部件摩擦。所以当没有摩擦时，时域波形看起来是正常的。

Harmonics and sub-harmonics and be generated because of the "non-linear" vibration and regions of the spectrum can be elevated due to resonance (the noise generated by the run excites the natural frequencies).

由于非线性振动和共振造成底部噪声抬起（运转时激发固有频率产生的噪声）会产生谐频和亚谐频。

Spectrum: Look for 1X and harmonics with a raised noise floor. Also look for sub-harmonics (1/2X, 1/3X, 1/4X, etc.).

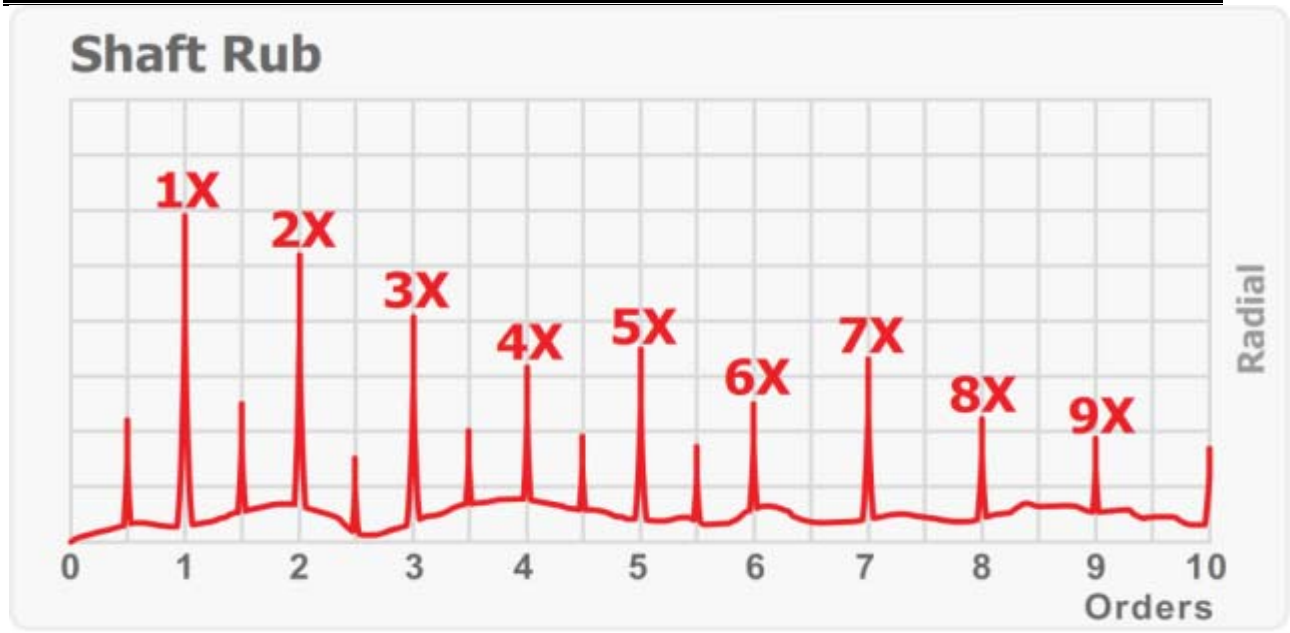
频谱：查看 1X 和谐频及其抬起的底部噪声。此外还查看（1/2X, 1/3X, 1/4X 等）

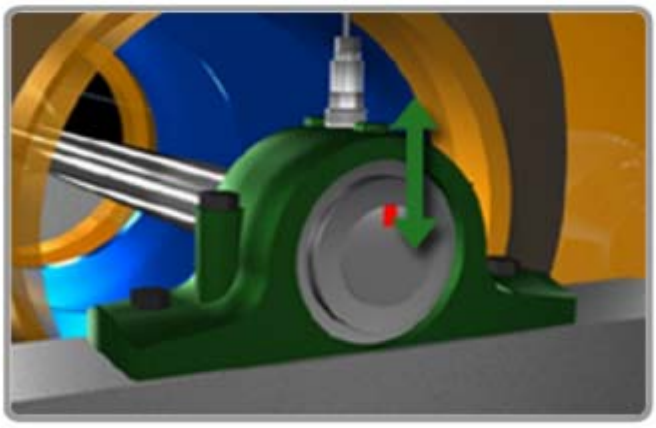
Phase: Phase will not be consistent due to the vibration motion generated.

相位：由于运动方式，相位不会一直稳定。

Waveform: In acceleration you may see high G levels. In velocity, look for "clipping" of the waveform. This is most easily observed in units of velocity and when you can see 10-15 cycles of rotation.

时域波形：加速度单位，会看到很高 G 值。速度单位，查看削波。当你看 10-15 周期的速度波形，很容易看到。





10 Eccentricity: Eccentricity general comments 偏心常规说明

Symptoms: 1X radial (V and H)特征 1X 径向（V 和 H）

Eccentricity occurs when the center of rotation is offset from the geometric centerline of a gear, bearing, pulley or rotor.

当齿轮、轴承、皮带轮或转子的旋转中心和几何中心有偏移时，会发生偏心。

Eccentric rotors/gears/pulleys will generate strong 1X radial components, especially in the direction parallel to the rotor/gear/pulley. This condition is common, and mimics unbalance.

This fault may present in a similar way to unbalance.

Spectrum: High 1X peak in vertical and horizontal. For gear eccentricity, expect to see 1X sidebands. For motor rotor eccentricity, expect to see pole-pass sidebands.

Waveform: The waveform will be very sinusoidal when viewed in velocity. Vibration from gears will also have gearmesh vibration and modulation of the turning shaft of the offending gear.

Phase: If belt driven, phase readings taken parallel and perpendicular to belts will either be in phase or 180° out of phase. For a direct driven component, vertical and horizontal readings will be 90° out of phase.

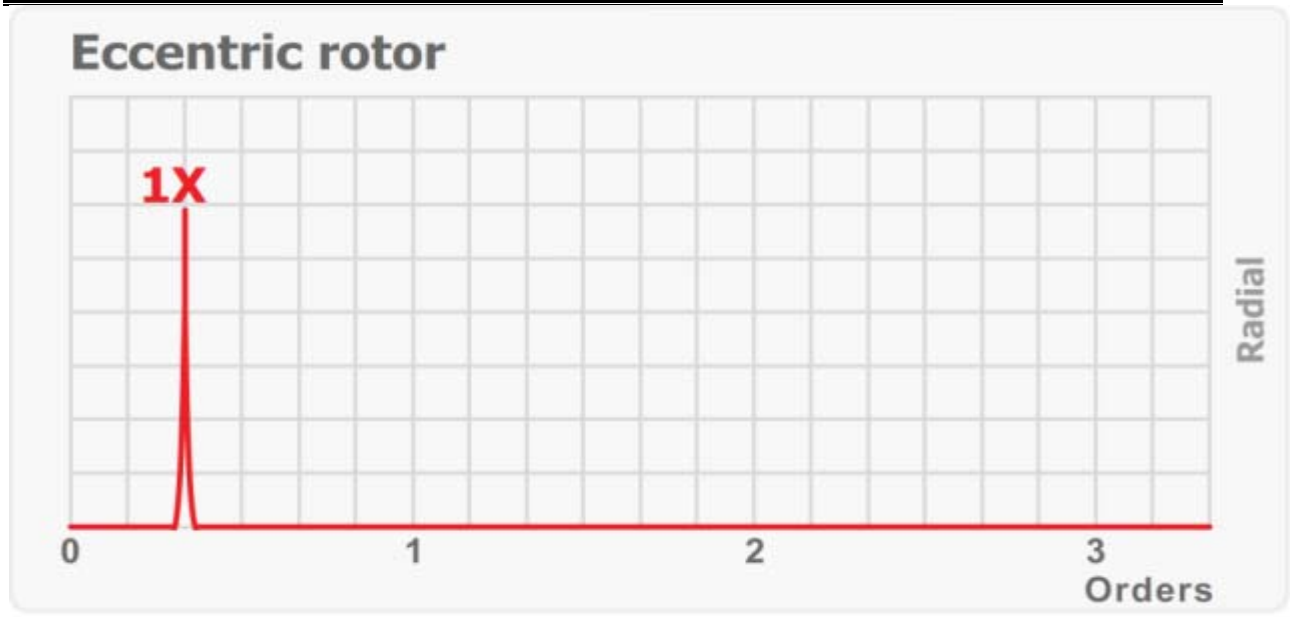
偏心转子/齿轮/皮带轮会产生很大的 1X 径向振动，特别是与转子/齿轮/皮带轮平行的方向。这种情况很常见，很像不平衡。

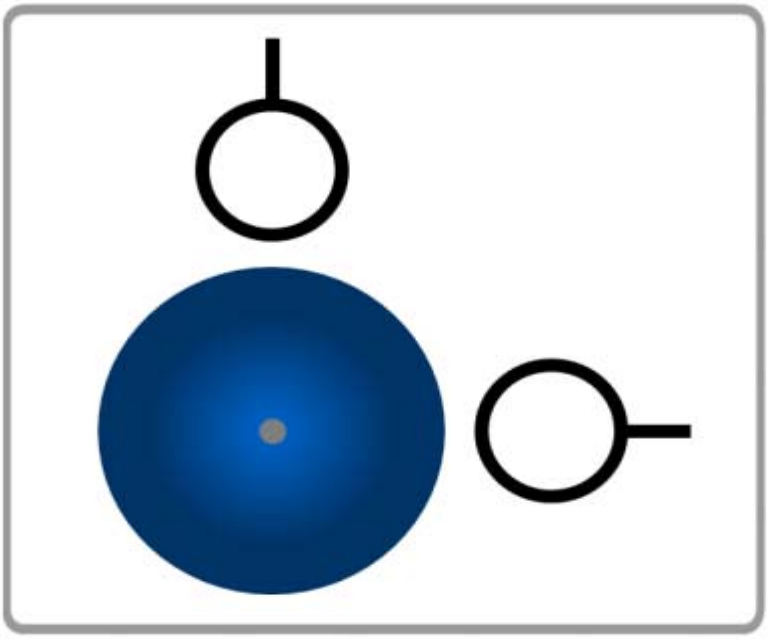
这种故障和不平衡表现类似。

频谱：垂直和水平方向 1X 幅值高。对于偏心的齿轮，会看到 1X 边带，对于偏心的电机转子，会看到极通过频率边带。

时域波形：速度单位，正旋波。对于齿轮，波形中会看到有故障齿轮的转频和齿轮啮合频率调制的波形。

相位：如果是皮带驱动，垂直与和平行于皮带的两个方向相位差是 0 或 180°。对于直接驱动的，垂直和水平相位差 90°。





10.1 Eccentricity: Eccentric motor rotor 偏心：电机转子偏心

Symptoms: Pole pass sidebands around 1xTS and 2xLF 特征：1X 转频±极通过频率边带和 2X 线频±极通过频率边带

Eccentric rotors produce a rotating variable air gap between the rotor and the stator

偏心的转子会在转子和静止间产生变化

which induces a pulsating source of vibration. You will see a peak at twice the line frequency (100 or 120 Hz); however there will also be pole pass sidebands around the 2xLF and the 1xTS peak.

Due to the eccentricity the 1xTS peak may be high.

The pole pass frequency is the slip frequency times the number of poles. The slip frequency is the difference between the actual RPM and the synchronous speed.

Spectrum: The key indicator is the presence of the pole-pass sidebands around 1xTS and 2xLF. You will need sufficient resolution to see those sidebands otherwise you will either miss them altogether, or confuse them for resonance (a broadening of the base of the peak).

Waveform: A waveform that covers many seconds of time will reveal the pole-pass frequency modulation. Due to a lack of impacting the waveform will be smooth; a combination of the 1xTS and the 2xLF vibration.

Phase: Not applicable unless the eccentric forces are great.

TS = Turning Speed

LF = Line Frequency (50 or 60 Hz)

的气隙，这会产生脉动。你会看到 2X 线频（100 或 120 Hz），会有 1X 转频±极通过频率边带和 2X 线频±极通过频率边带。

由于偏心，1X 转频幅值会高。

极通过频率是滑差频率乘以级数。滑差频率是实际转速和同步转速直接的差值。

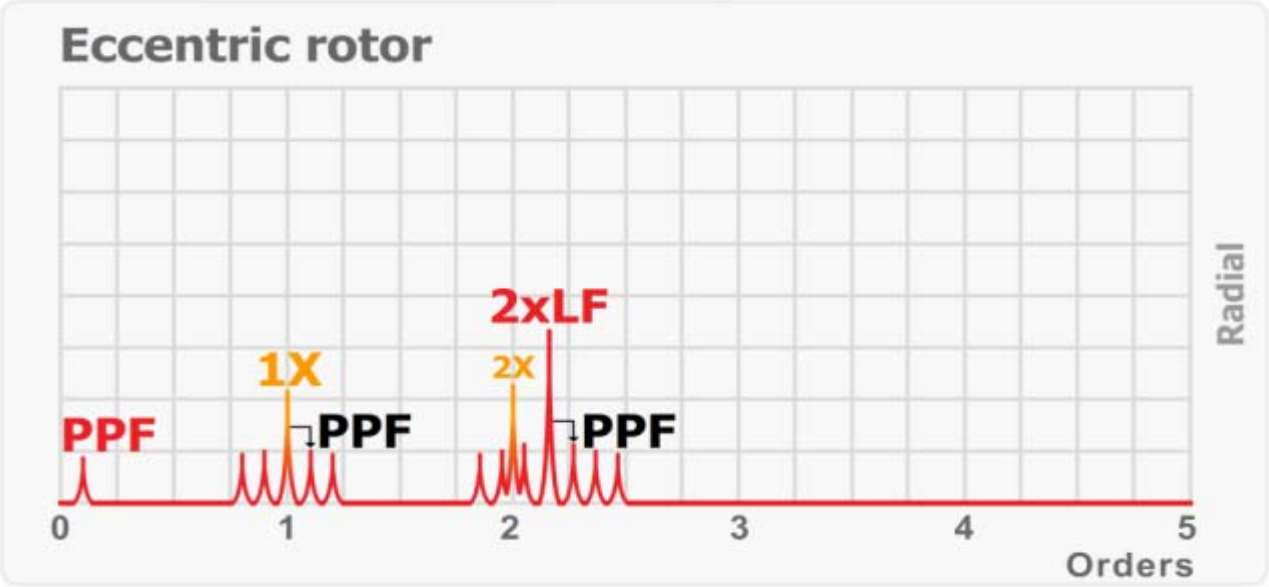
频率：关键指标是 1X 转频±极通过频率边带和 2X 线频±极通过频率边带。需要足够的分辨率以便查看边带，否则会遗漏它们或与共振混淆（峰值的底部噪声抬起）

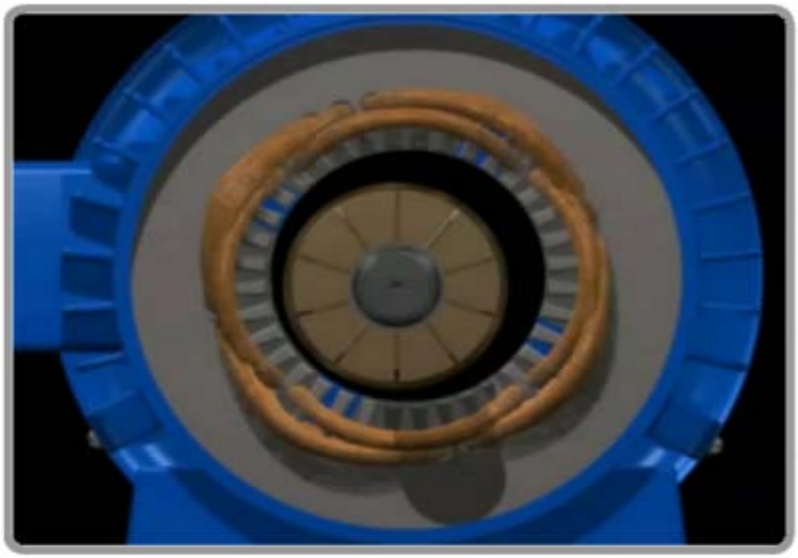
时域波形：时域波形需要足够长，才能看到极通过频率调制。由于没有冲击，波形很平滑。是 1X 转频和 2X 线频的组合。

相位：除非偏心力非常大，否则不适用。

TS=旋转速度

LF=线频（50 或 60Hz）





10.2 Eccentricity: Eccentric motor stator 偏心：电机定子偏心

Symptoms: Twice line frequency (100 or 120 Hz) radial 特征：2X 线频（100 或 120 Hz)）径向

Stator problems will generate high vibration at twice the line frequency (100 or 120 Hz). Stator eccentricity produces an uneven stationary air gap between the rotor and

定子故障会产生很高 2X 线频振动。定子偏心会在转子和定子间产生不均匀间

stator that produces a very directional source of vibration.

A stator may become eccentric due to soft foot. See the section on soft foot for more details.

Spectrum: The peak at 2xLF will be high. For a two-pole motor this peak will be close to 2xTS running speed – you will need sufficient resolution to separate them.

A live spectrum may reveal beating – the 2xLF and 2X peak may appear to rise and fall if you do not have sufficient resolution to separate the peaks.

The vibration will be strongest at the point(s) where the stator is closest to the rotor. Move the accelerometer around the motor housing to see if the peak is highest in one or two locations.

Waveform: The waveform will be a combination of 1xTS, possibly 2xTS and 2xLF and may therefore include a "wobble" or take on the "M" or "W" shape. Beating between 2xLF and 2xTS (2-pole motor) may be observed if the time waveform covers more than a few seconds.

TS = Turning Speed

LF = Line Frequency (50 or 60 Hz)

隙，这样会产生定向的振动。

软角会造成定子偏心。查看软脚部分，了解更多。

频谱：2X 线频幅值会很高。对于 2 级电机，2X 转频和该频谱会接近-需要足够的分辨率进行区分。

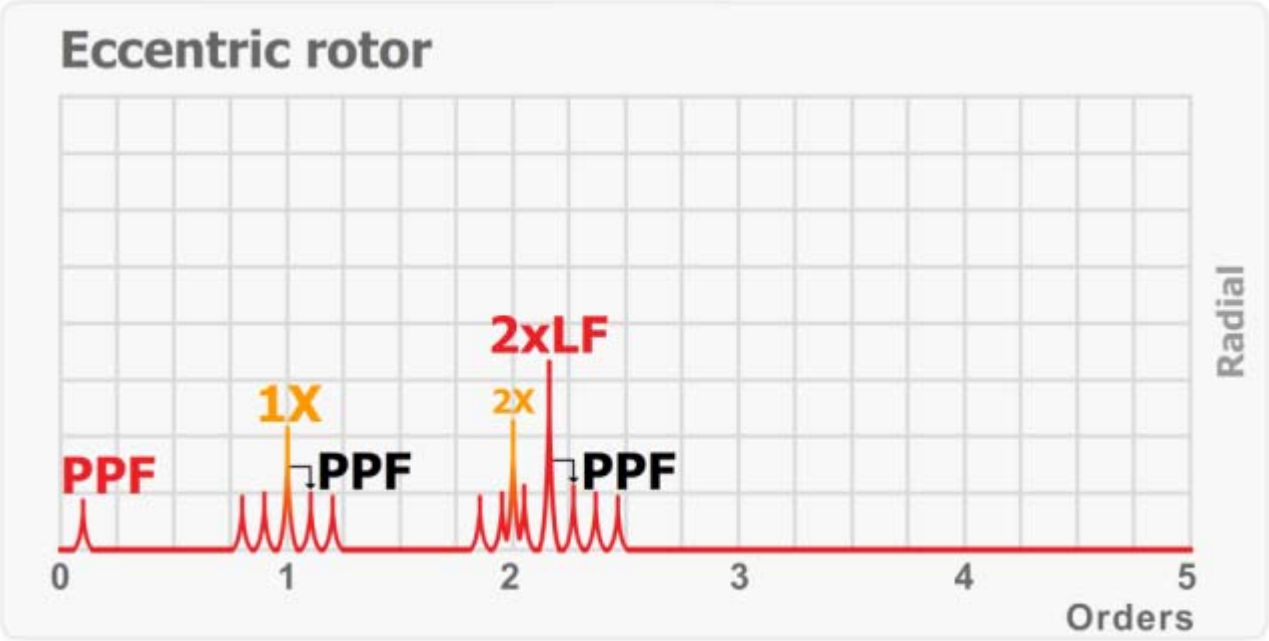
如果频谱分辨率不能区分两个峰值，实时频谱会显示拍振，2X 转频和 2X 线频的峰值会上升和下降。

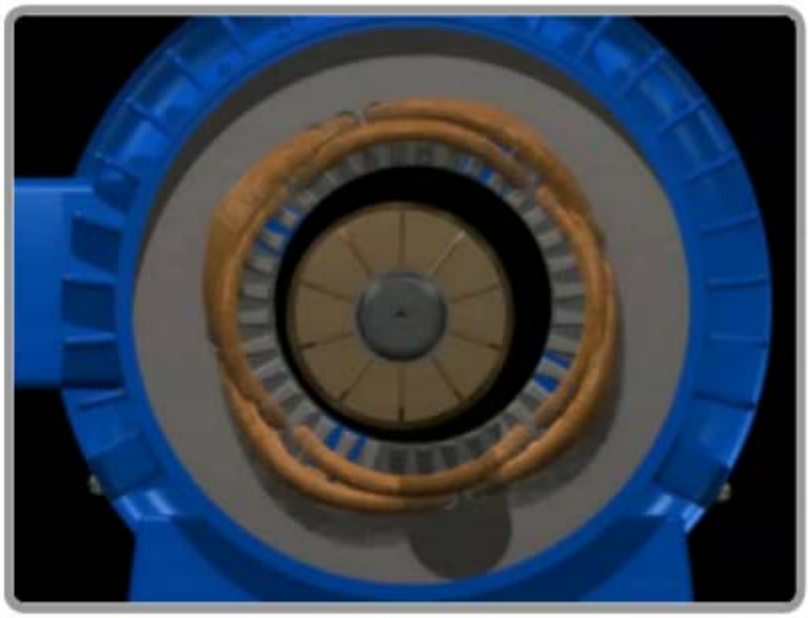
定子最接近于转子的地方，振动最大。绕电机外壳移动加速度传感器，查看哪一个或两个峰值最高。

时域波形：时域波形中包括 1X 转频、2X 转频和 2X 线频，形状会是“抖动”或“M”或“W”。如果波形时间长度过长，能看到 2X 线频和 2X 转频（2 级电机）间的拍振。

TS=旋转速度

LF=线频（50 或 60Hz）





10.3 Eccentricity: Eccentric pulley or sheave 偏心：皮带轮或槽轮偏心

Symptoms: 1X radial (V and H)特征：1X 径向（V 和 H）

Eccentricity occurs when the center of rotation is offset from the geometric centerline of a sheave (pulley).

当皮带轮（槽轮）的旋转中心和几何中心有偏移时，会发生偏心。

Eccentric sheaves will generate strong 1X radial components, especially in the direction parallel to the belts. This condition is common, and mimics unbalance.

There will be a high 1X vibration level on both components (motor and fan for example), however due to the change in speed, these will be at two different frequencies.

Eccentricity can be checked by removing the belt(s) and checking again for the 1X peak on the motor.

Spectrum: It is best to collect spectra parallel and perpendicular to belts instead of pure vertical and horizontal. Expect a high 1X peak. Amplitude will be higher in the direction parallel with belts.

Waveform: The waveform will be very sinusoidal when viewed in velocity.

Phase: Phase readings taken parallel and perpendicular to belts will either be in phase or 180° out of phase.

偏心皮带轮会产生很大的 1X 径向振动，特别是与皮带轮平行的方向。这种情况很常见，很像不平衡。

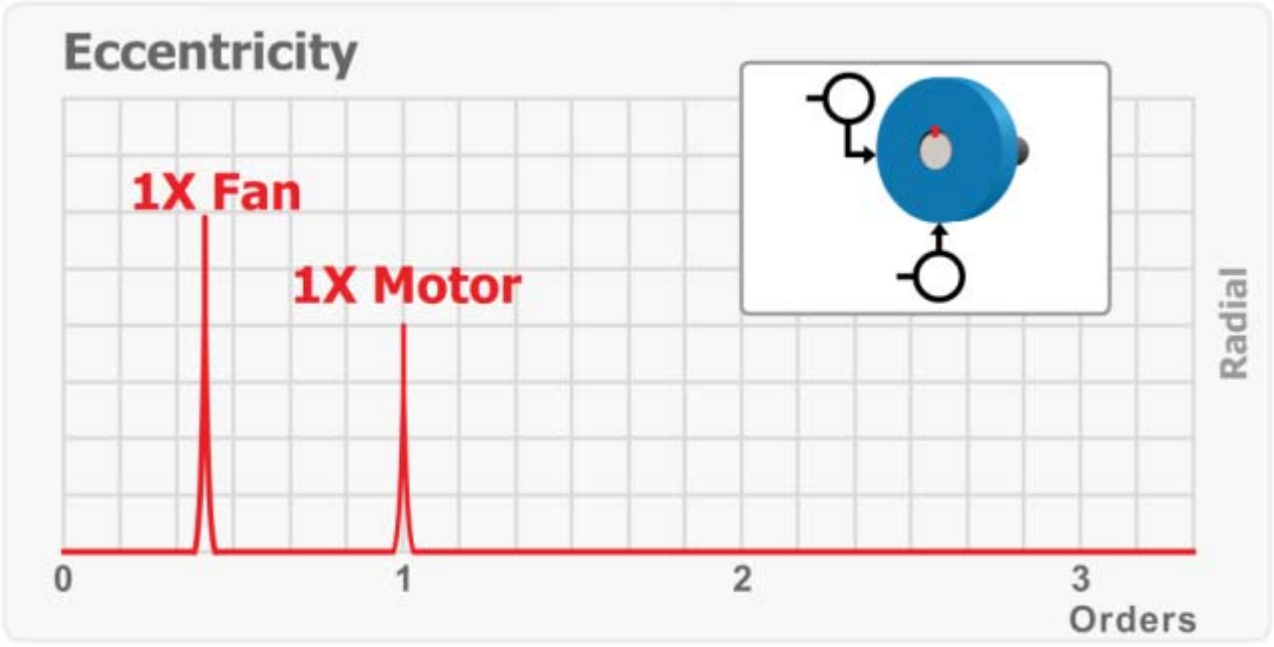
传动的部件都会有很高的 1X 振动（电机和风机为例），但是由于部件速度不一样，所以会有两个不同频率。

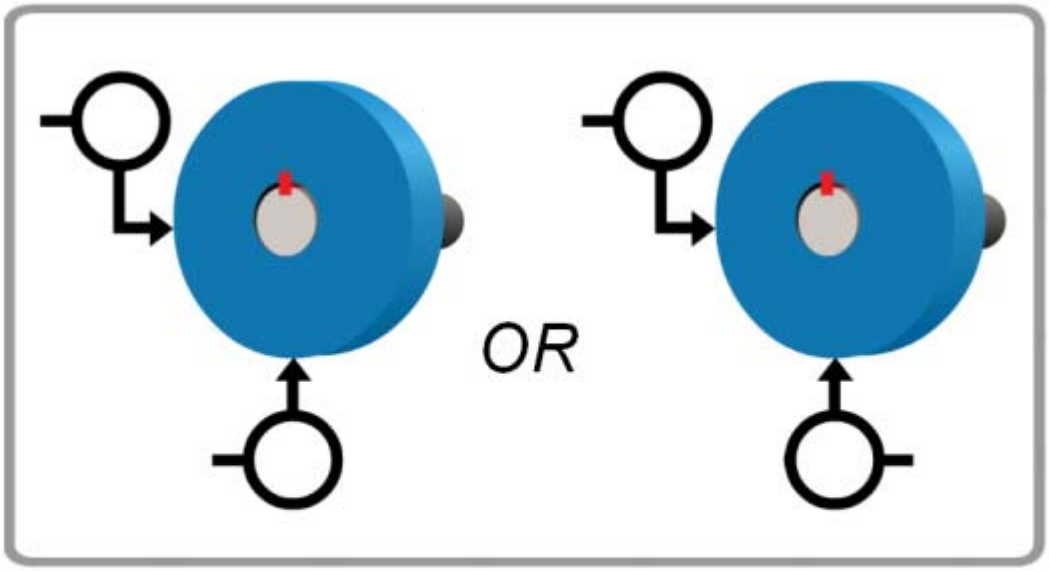
偏心可以通过卸下皮带，再次检查电机 1X 峰值进行确认。

频谱：最后采集垂直与和平行于皮带两个方向的振动而非绝对垂直和水平。会看到很高 1X 的峰值。平行于皮带方向的幅值会更高。

时域波形：速度单位，正旋波。

相位：如果是皮带驱动，垂直与和平行于皮带的两个方向相位差是 0 或 180°。





10.4 Eccentricity: Eccentric gear 偏心：齿轮偏心

Symptoms: 1X radial (V and H) and sidebands 特征：1X 径向（V 和 H）和边带

Eccentricity occurs when the center of rotation is offset from the geometric centerline of the gear.

当齿轮的旋转中心和几何中心有偏移时，会发生偏心。

Eccentric gears will generate strong 1X radial components, especially in the direction parallel to the gear.

Eccentric gears will generate sidebands of the turning speed of the eccentric gear around the gearmesh peak. Natural frequencies may also be excited, and harmonics of gearmesh may be generated.

Waveform: The waveform will have a combination of 1X turning speed of input and output shaft, plus strong gearmesh vibration modulated by the turning speed of the shaft with the eccentric gear.

Spectrum: High gearmesh peak with sidebands of the turning speed of the shaft with the eccentric gear.

Phase: Not applicable.

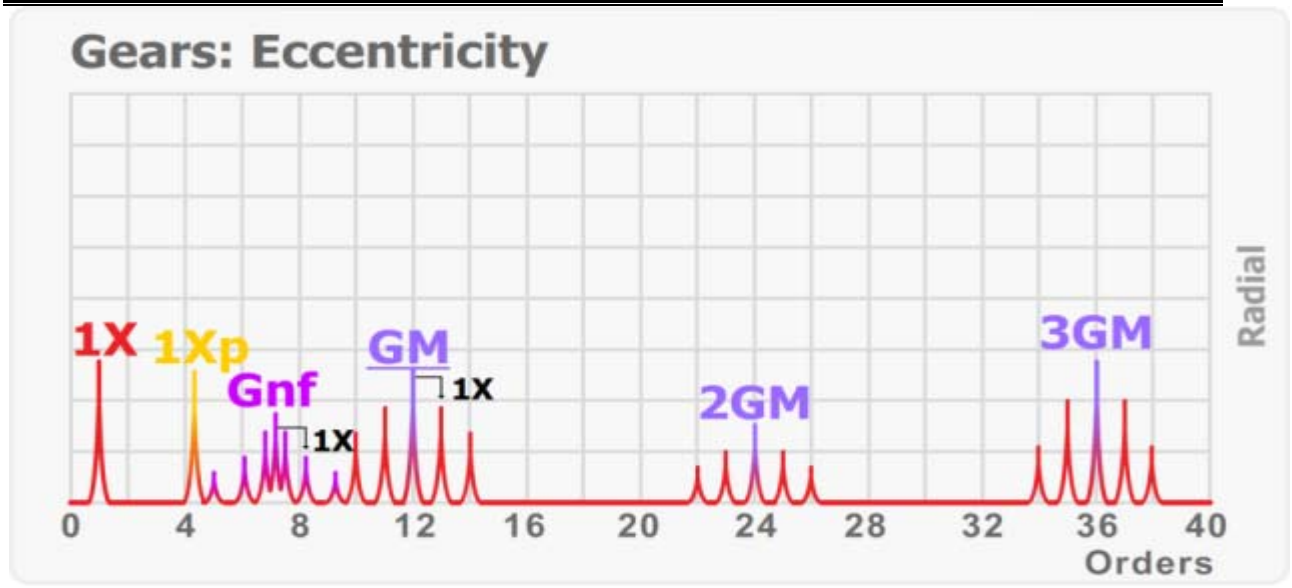
偏心齿轮会产生很大的 1X 径向振动，特别是与齿轮平行的方向。

偏心齿轮会产生啮合频率及故障齿轮的边带。固有频率也可能激起，并产生啮合频率的谐频。

时域波形：时域波形包括 1X 输入和输出轴，还有故障齿轮的转频和齿轮啮合频率调制。

频谱：高幅值的齿轮啮合频率及偏心齿轮的边带。

相位：不适用。



11 Hydraulic and aerodynamic 流体

11.1 Hydraulic and aerodynamic: Blade faults 流体：叶片故障

Symptoms: Peak at vane pass or blade pass 特征：叶片或叶轮通过频率峰值

All pumps, fans and compressors will normally have a peak in the spectrum at the

所有的泵、风机和压缩机的频谱中通常

"blade pass" or "vane pass" frequency. This is the number of blades or vanes multiplied by the shaft speed.

The amplitude of the peak can increase if the gap between the blades or vanes and the stationary diffusers is not kept equal. It is also caused by obstructions and sharp bends in the flow path, in this case at the edge of the volute where it meets the discharge passage.

Vane pass = Number of vanes x RPM

Blade pass = Number of blades x RPM

Spectrum: It is normal to see a peak at the blade pass or vane pass frequency. Harmonics may exist, and sidebands of the operating speed will occur when the vibration is rising and falling with each rotation.

- Vane pass = Number of vanes x RPM
- Blade pass = Number of blades x RPM

Waveform: Pulsations may be visible in the waveform at the vane pass or blade pass frequency. The waveform must not have too many shaft rotations or else it will be very difficult to notice the pulsations generated as each vane or blade passes the accelerometer.

会有叶片或叶轮通过频率。等于叶片或叶轮乘以转轴速度。

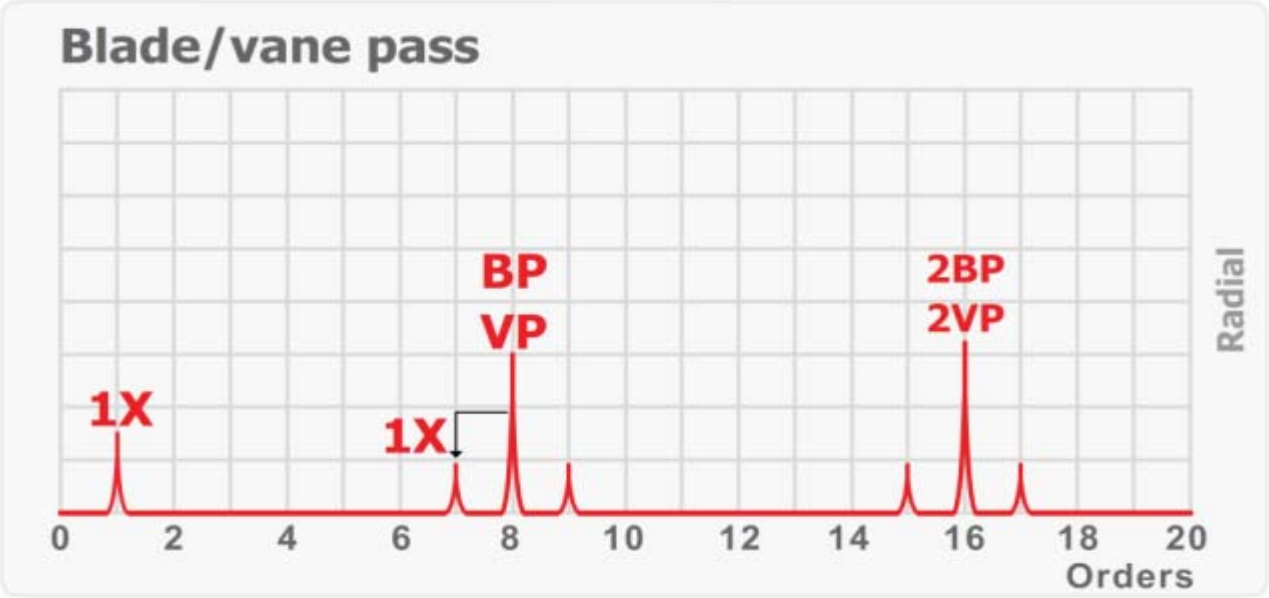
如果叶片或叶轮和静止的扩压器之间的间隙不均匀，会产生很高的叶片或叶轮通过频率。也可能是堵塞物或管路中的急弯引起的-涡壳和出口管道交汇的地方。

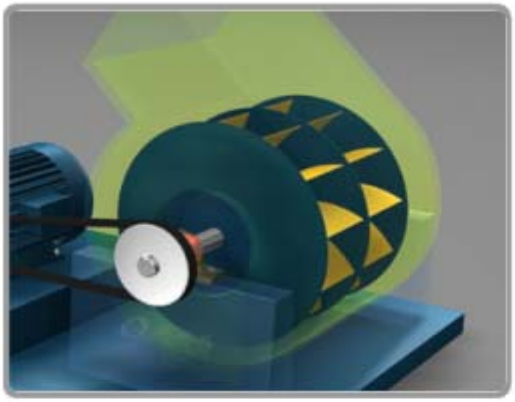
Vane pass=叶轮数 XRPM

Blade pass=叶片数 XRPM

频谱：会看到叶片或叶轮通过频率，可能会有谐频，当每周期内振动上下波动时，会有转速边带。

时域波形：可能看到叶片或叶轮通过频率的脉冲。采用加速度传感器，波形的时间长度不要是很多旋转周期，不然看到叶片或叶轮通过频率的每次脉冲很困难。





11.2 Hydraulic and aerodynamic: Flow turbulence 流体：湍流

Symptoms: Random vibration in the range 50 to 2000 CPM 特征：50-2000CPM 随机振动

Flow turbulence is due to variations in pressure or velocity of the air passing through the fan or blower.

空气通过风机或鼓风机时，空气压力或速度波动产生湍流。

This phenomenon generates random, low frequency vibration. It will typically be observed in the range of 50 to 2000 CPM.

Spectrum: It is normal to see a peak at the blade pass or vane pass frequency. Harmonics may exist, and sidebands of the operating speed will occur when the vibration is rising and falling with each rotation.

Waveform: Pulsations may be visible in the waveform at the vane pass or blade pass frequency. The waveform must not have too many shaft rotations or else it will be very difficult to notice the pulsations generated as each vane or blade passes the accelerometer.

这种现象会产生随机，低频振动。通常50-2000CPM。

频谱：会看到叶片或叶轮通过频率，可能会有谐频，当每周期内振动上下波动时，会有转速边带。（与下面故障图谱不符-mobius 有误）

时域波形：可能看到叶片或叶轮通过频率的脉冲。采用加速度传感器，波形的时间长度不要是很多旋转周期，不然看到叶片或叶轮通过频率的每次脉冲很困难。（与下面故障图谱不符-mobius 有误）

11.3 Hydraulic and aerodynamic: Pump cavitation 流体：泵气蚀

Symptoms: High frequency "noise"特征：高频“噪声”

Cavitation normally indicates insufficient suction pressure or starvation - i.e. low inlet pressure.

气蚀通常是进口管道压力不足造成的。

Cavitation normally creates random, higher frequency vibration or "noise". It is often observed as a "hump" in the high frequency range of the spectrum (exciting resonance) and as a hump around the base of the pump vane rate peak.

气蚀通常会产生随机、高频振动或“噪声”。频谱的高频区域会有“驼峰”（激起共振，和叶片通过频率的底部噪声也会抬起。

12 Analysis Definitions: Reciprocating machines 往复设备

Symptoms: 0.5X peak for a four-stroke engine / 1X peak for a two-stroke engine 四冲程发动机 0.5X/两冲程发动机 1X

The vibration level on reciprocating machinery is commonly very high.

If you have a four-stroke engine, then the engine fires every other rotation, which will result in a strong peak at 0.5X.

In the case of a two-stroke engine, such as many diesels, the engine will fire for every stroke; therefore you will see a strong 1X peak.

Spectrum: Look for the 1X peaks (two-stroke engine) or 0.5X peaks (four stroke engine).

Waveform: Pulses of vibration occur when the engine fires. These can be view in the waveform. The time base needs to be set so that you can see 6-10 rotations for a two-stroke engine, and 15-20 rotations for a four stroke engine.

Special monitoring systems are available for testing reciprocating engines.

往复设备的振值一般都很高。

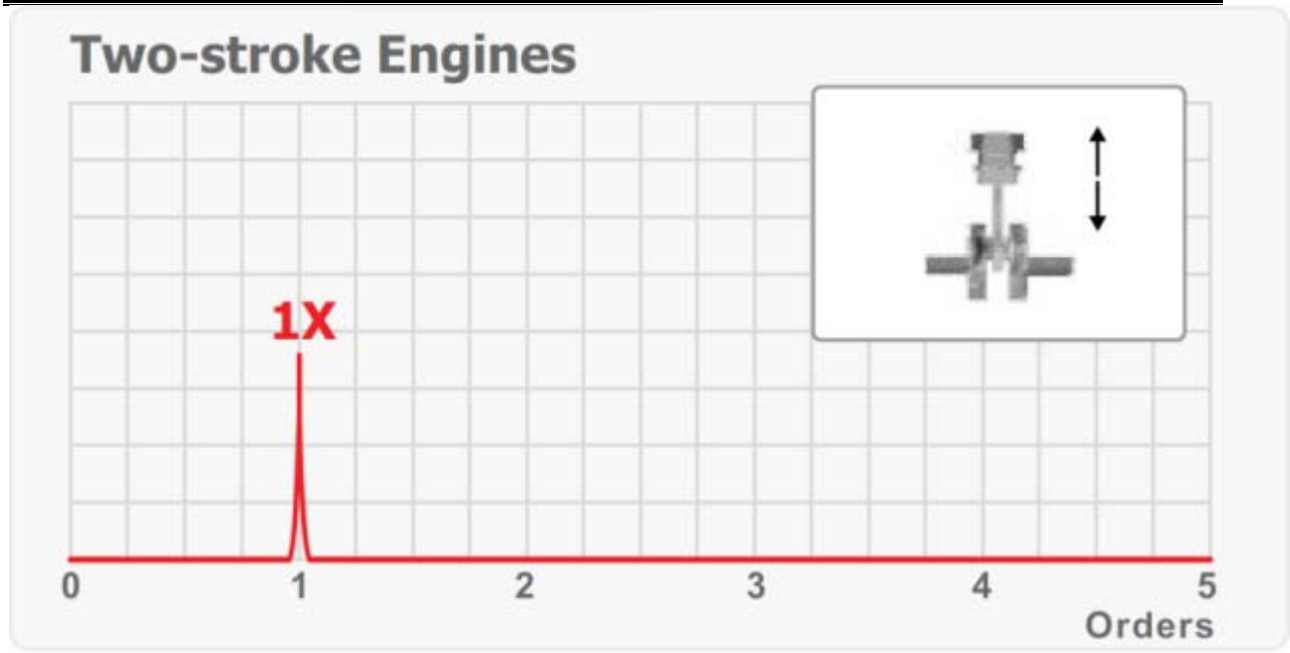
对于四冲程发动机，隔一周点火一次，会产生很大的 0.5X。

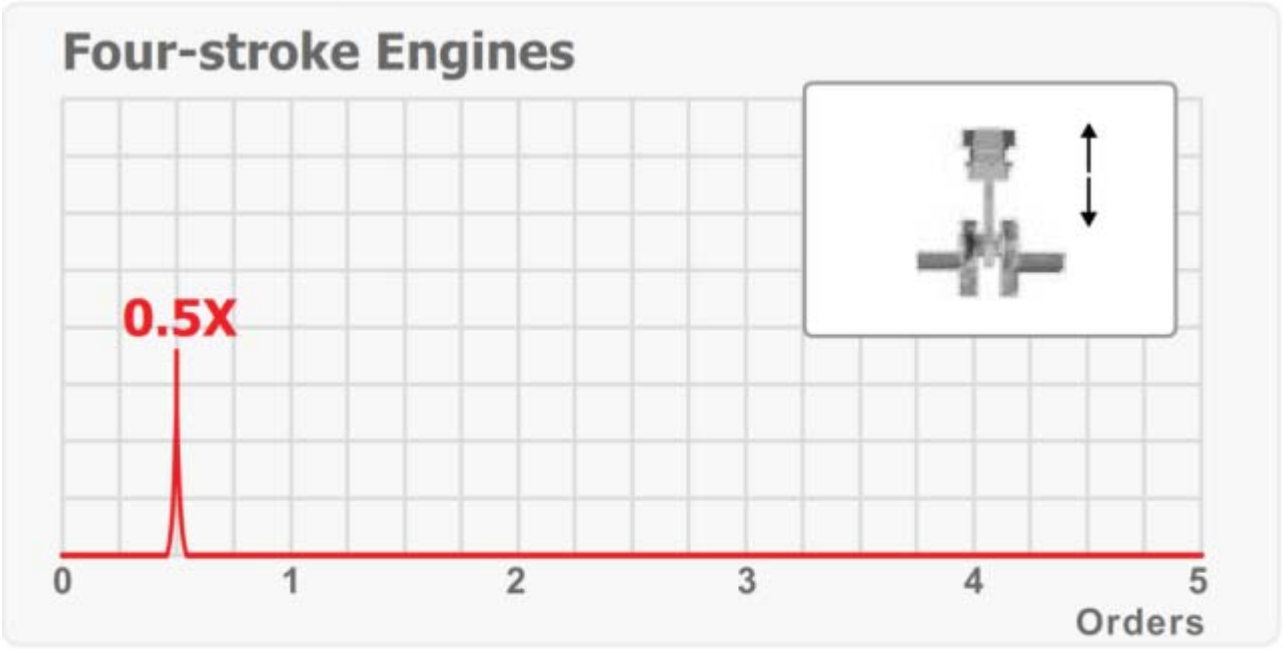
对于两冲程发动机，如柴油机，每冲程点火一次，所以会产生很多的 1X。

频谱：查看 1X 峰值（两冲程）或 0.5X 峰值（四冲程）

时域波形：发动机点火时会有脉冲。波形时间长度，对于两冲程 6-10 周，对于四冲程 15-20 周。

专门的监测系统可用于往复设备监测。


Two-stroke Engines
1X
0
1
2
3
4
5
Orders


Four-stroke Engines
0.5X
0
1
2
3
4
5
Orders

13 Induction motors 异步电机

13.1 Induction motors: Type I rotor faults 异步电机：I 型转子故障

Symptoms: Pole pass sidebands around 1X and harmonics 特征：1X±极通过频率及谐频

Cracked or broken rotor bars, shorted end rings or rotor laminations, or loose rotor bar joints, can cause the spectrum to develop a series of harmonics of turning speed (typically 1X-4X) with sidebands of the pole pass frequency. Being a very low frequency it is necessary to use a high resolution spectrum.

转子条断裂，断环或转子铁芯短路，转子条节点松动，可以导致频谱中出现 1X-4X±极通过频率。由于是低频，高分辨率很有必要。

Given the low frequency sidebands you will need a high resolution spectrum, and there will be beating which should be audible and visible in the waveform or in a live spectrum.

由于是低频率边带，需要高分辨率的频谱。波形或实时频谱能看到和听到拍振。

Please also look up information on the individual fault conditions.

也要查看各个故障的状态信息。

Spectrum: Look for the pole-pass sidebands around 1X, 2X, 3X, and 4X. A high resolution spectrum will be required. Viewing with a log y-axis can help. Watching a live spectrum will reveal beating.

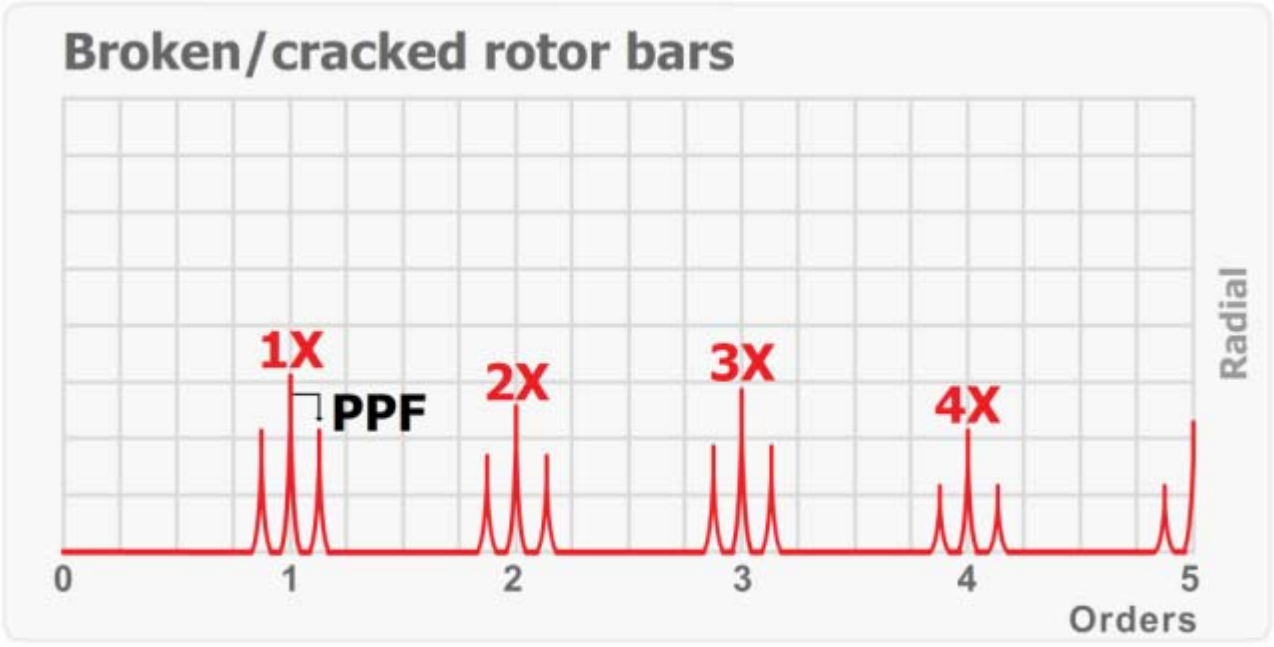
频谱：查看 1X、2X、3X、4X 及其极通过频率，需要高分辨率频谱。Y 轴采用对数坐标，会有帮助。实时频谱会显示拍振。

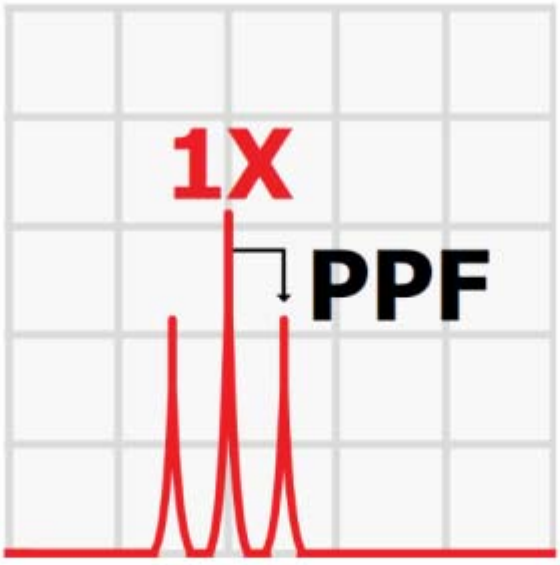
Waveform: A waveform with a time base of at least 10 seconds will reveal beating. Listen to the vibration for beating.

时域波形：最少 10s 的波形，会显示拍振。听下拍振的振动。

Motor current analysis: Using a current clamp, take a high resolution spectrum around line frequency (50 Hz or 60 Hz). Displayed in log format you are looking for the difference between the height of the line frequency peak and the first pole-pass sideband.

电机电流分析：使用电流钳，采集线频（50 或 60）附近的高分辨率频谱。当查看线频峰值和极通过频率的差值时，采用对数谱。





13.2 Induction motors: Type II rotor faults 异步电机：II 型转子故障

Symptoms: 2xLF sidebands around RBF 特征：RBF±2x 线频

Cracked or broken rotor bars, loose (or otherwise defective) rotor bar joints, arcing between the rotor bars and end ring, or	转子条断裂，转子条节点松动（或其它故障），转子条和端环间的电弧，或转

porosity in the rotor bar castings will all cause a disruption in the magnetic field. The pulsation will generate an elevated rotor bar passing frequency (RBF) which will rise and fall due to the electrical forces called "magnetostriction" – therefore we see 2xLF sidebands. Occasionally the modulation will instead be at the turning speed (1X sidebands).

Please also note that if there is a break or crack there may be local heating and the rotor may bow.

Rotor bar pass frequency (RBF) = Number of rotor bars X Running speed

2xLF = Twice line frequency (100 or 120 Hz)

Spectrum: The Fmax will need to be high enough to see the RBF frequency (plus 2xLF sidebands). 2xRBF (with sidebands) may also be present. Note that sometimes you will see a high peak at RBF + 2xLF whereas RBF and RBF – 2xLF may be quite small.

Motor current analysis: Using a current clamp, take a high resolution spectrum around line frequency (50 Hz or 60 Hz). Displayed in log format you are looking for the difference between the height of the line frequency peak and the first pole-pass sideband.

子条铸件中的气孔都会导致磁场干扰。电磁力（也称磁致伸缩）会产生脉动，上升和下降的转子条通过频率（RBF），所以也会有 2X 线频边带。偶尔也会被 1X 转频调制。

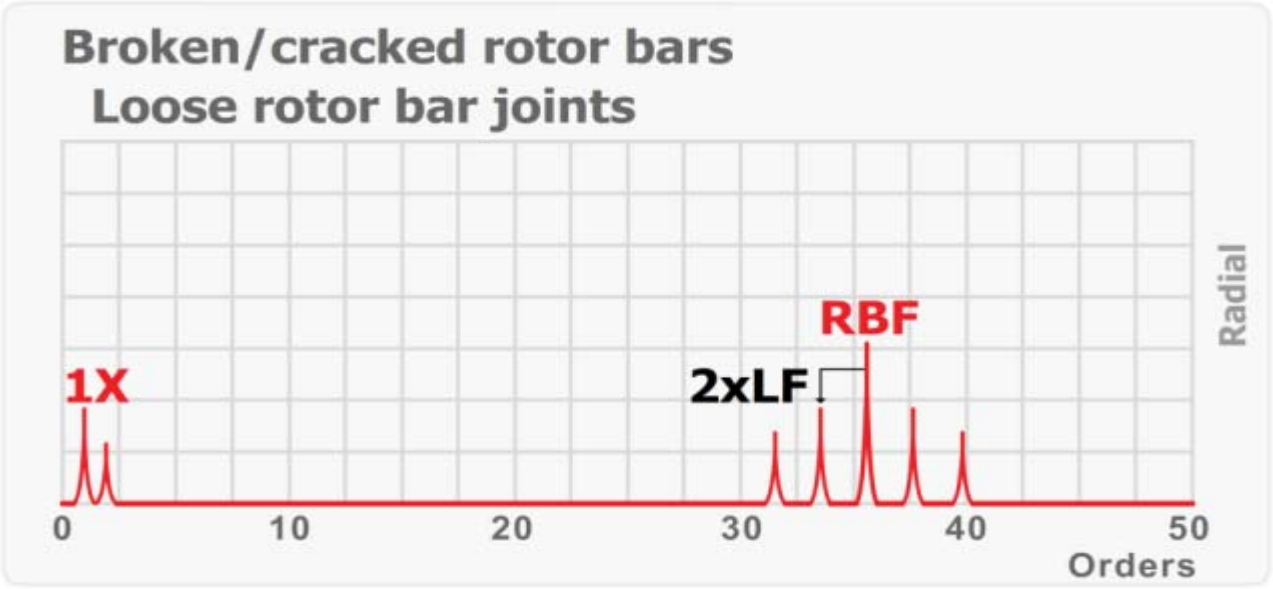
另请注意，如果转子条断条或裂纹，可能局部会发热，转子便弓形。

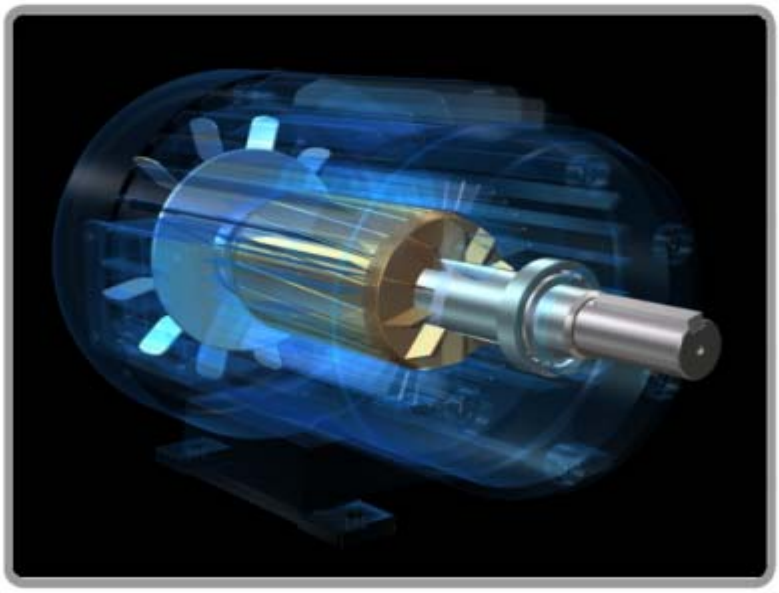
RBF=转子条 X 转频

2xLF=2 倍线频（100 或 120Hz）

频谱：分析频率需要足够高，以便查看 RBF 和 2X 线频，2XRBF 及边带可能出现。需要注意的是，有时你会看到 RBF +2X 线频的幅值很高，而 RBF -2X 线频的幅值很低。

电机电流分析：使用电流钳，采集线频（50 或 60）附近的高分辨率频谱。当查看线频峰值和极通过频率的差值时，采用对数谱。





13.3 Induction motors: Stator eccentricity or soft foot 异步电机：定子偏心或软角

Symptoms: Twice line frequency (100 or 120 Hz) radial 特征：2X 线频（100 或 120 Hz）径向

Soft foot and warped bases can produce an eccentric stator. Altering the tension on the

软脚和翘起的基础可以导致定子偏心。

hold down bolts, or repairing the foundation can resolve this problem.

Spectrum: The peak at 2xLF will be high. For a two-pole motor this peak will be close to 2X running speed – you will need sufficient resolution to separate them.

A live spectrum may reveal beating – the 2xLF/2xTS peak may appear to rise and fall if you do not have sufficient resolution to separate the peaks.

The vibration will be strongest at the point(s) where the stator is closest to the rotor. Move the accelerometer around the motor housing to see if the peak is highest in one or two locations.

Waveform: The waveform will be a combination of 1xTS, possibly 2xTS and 2xLF and may therefore include a "wobble" or take on the "M" or "W" shape. Beating between 2xLF and 2xTS (2-pole motor) may be observed if the time waveform covers more than a few seconds.

TS = Turning Speed

LF = Line Frequency (50 or 60 Hz)

调制螺栓张紧程度或修复基础可以解决该故障。

频谱：2X 线频幅值会很高。对于 2 极电机，2X 线频和 2X 转频很接近，需要提供分辨率，才能区分两个峰值。

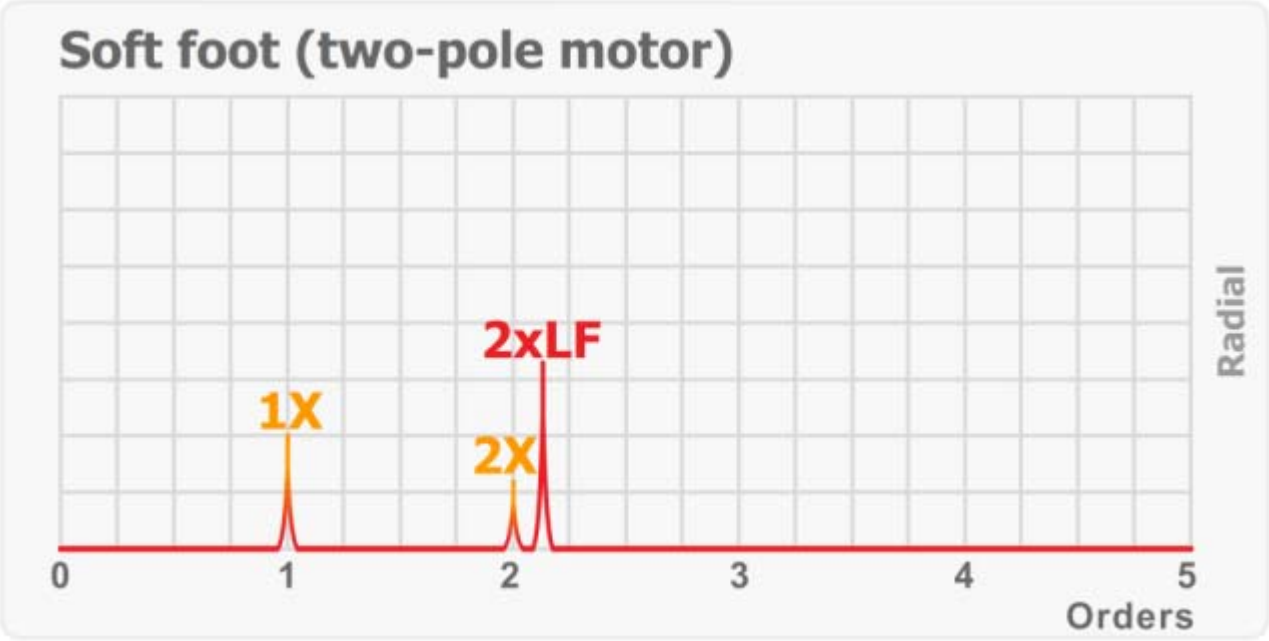
如果频谱分辨率不能区分两个峰值，实时频谱会显示拍振，2X 转频和 2X 线频的峰值会上升和下降。

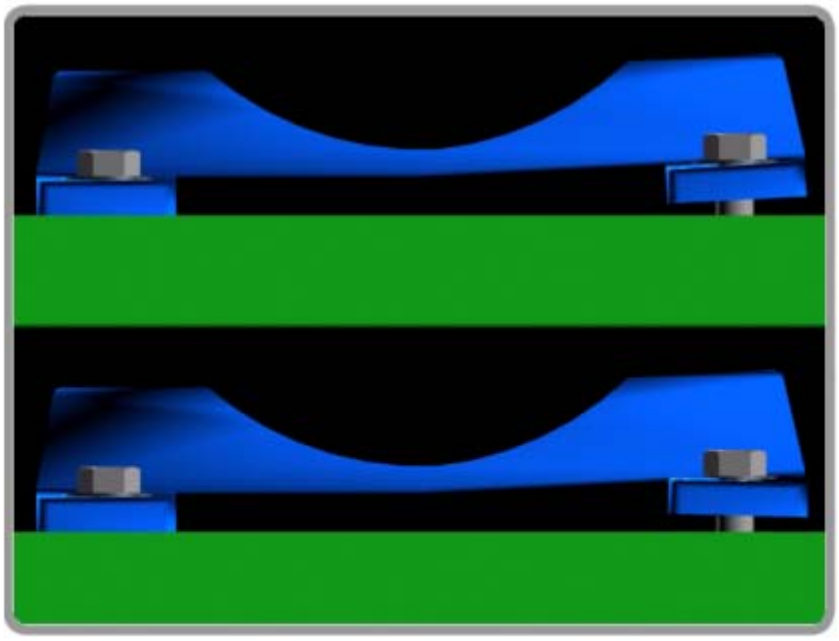
定子最接近于转子的地方，振动最大。绕电机外壳移动加速度传感器，查看哪一个或两个峰值最高。

时域波形：时域波形中包括 1X 转频、2X 转频和 2X 线频，形状会是“抖动”或“M”或“W”。如果波形时间长度过长，能看到 2X 线频和 2X 转频（2 级电机）间的拍振。

TS=旋转速度

LF=线频（50 或 60Hz）





13.4 Induction motors: Rotor bow 异步电机：转子弓形

Symptoms: 1X radial 特征：1X 径向

Rotor bow on a motor will present like static unbalance. Broken rotor bars or other fault conditions that result in uneven current flow

电机的转子弓形会像静不平衡。转子条断裂或其它故障导致转子电流不平衡，

in the rotor will result in localized heating, which will in turn cause the rotor to bow. The bow creates an unbalance condition (uneven weight distribution around the centerline of the shaft). Therefore we see a high amplitude peak at 1X turning speed in the radial (vertical and horizontal) directions.

这样会产生局部过热，进而导致转子弓形。弓形产生不平衡状态（绕转轴中心线质量不均匀分布）。所以我们看到 1X 转频径向（垂直和水平）幅值很高。

You may also see the effect of a rotating air gap – high peak at twice line frequency (100 or 120 Hz) with pole-pass sidebands around 1X and 2X.

由于旋转气隙的影响，也会看到 2X 线频幅值很高，1X、2X 有极通过频率边带。

This fault may present in a similar way to static unbalance and eccentricity – except when the rotor cools down the rotor may become straight again.

该故障和静不平衡和偏心很像，除非转子停下来冷却后，转子重新变直。

Spectrum: High 1X peak in vertical and horizontal. There may be a 2X peak if the bend is more severe. There may be pole-pass sidebands around 1X and 2X due to the rotating differential air gap.

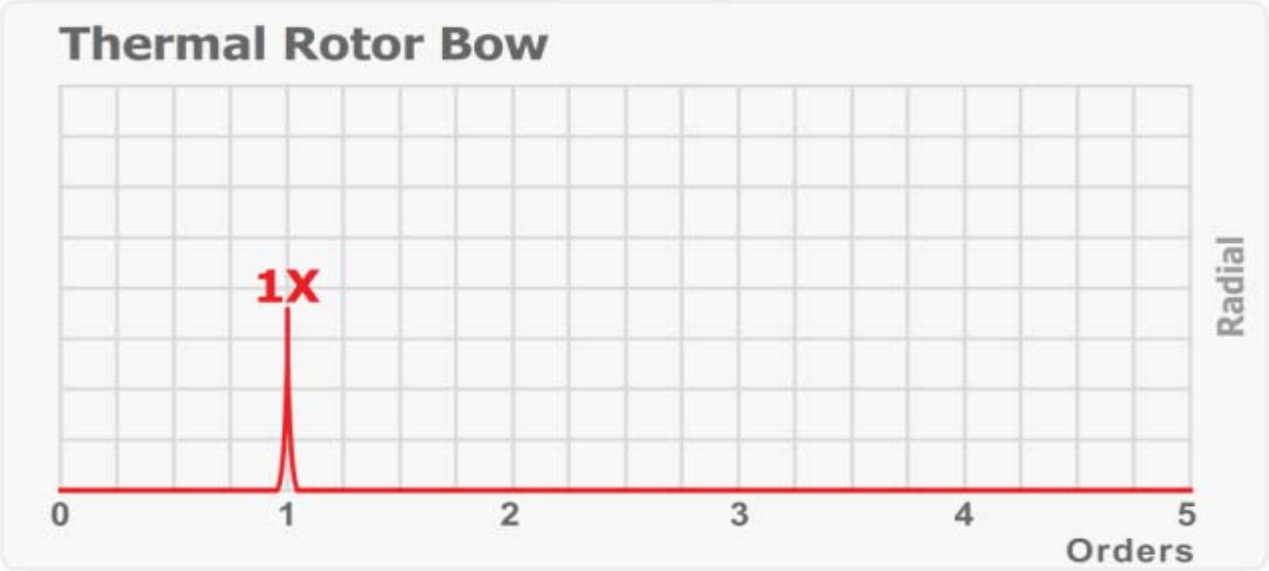
频谱：垂直和水平 1X 幅值高。如果弯的严重，会有 2X 幅值。由于变化的旋转气隙，1X、2X 有极通过频率边带。

Waveform: The waveform will be very sinusoidal when viewed in velocity.

时域波形：速度单位，正旋波。

Phase: Look for 90° phase shift between vertical and horizontal axes. The inner race will move in and out once per revolution with a bent shaft, so look for consistent phase readings around the shaft.

相位：垂直和水平相位 90°相位差。轴弯时每转一圈，轴承内圈来回移动所以，同一轴承端面的轴向相位同相。



13.5 Induction motors: Cracked or broken rotor bars 异步电机：转子条断条

Symptoms: Pole pass sidebands around 1X and harmonics OR 2xLF sidebands around RBF 特征：1X±极通过频率及谐频或 RBF±2X 线频

When there is a disruption in the current flowing through the rotor bars of an

由于转子条断裂或裂纹导致电流通过

induction rotor due to a crack or break, the vibration can change in one of two ways.

Type I: The 1X peak and harmonics (typically up to 4X) will have pole-pass sidebands. 2xLF may be quite low.

Type II: The rotor bar passing frequency (RBF) peak can increase in amplitude, and there will be 2xLF sidebands.

Please also note that if there is a break or crack there may be local heating and the rotor may bow.

Rotor bar pass frequency (RBF) = Number of rotor bars X Running speed

2xLF = Twice line frequency (100 or 120 Hz)

Also see Type I and Type II rotor faults under Electric motor faults

Spectrum: Type I: A high resolution spectrum will be required in order to see the pole-pass sidebands. A log y-axis will help. **Type II:** The Fmax will need to be high enough to see the RBF frequency (plus 2xLF sidebands). 2xRBF may also be present. (This is a common pattern and does not necessarily indicate a fault condition. Investigate if the amplitude increases.)

Waveform: Type I: A waveform with a time base of at least 10 seconds will reveal beating. Listen to the vibration for beating.

Motor current analysis: Using a current clamp, take a high resolution spectrum around line frequency (50 Hz or 60 Hz). Displayed in log format you are looking for the difference between the height of the line frequency peak and the first pole-pass sideband.

时会有干扰，会产生两种方式的振动。

I 型：1X-4X±极通过频率，2X 线频幅值较低。

II 型：RBF 幅值会变大，会有 2X 线频边带。

另请注意，如果转子条断条或裂纹，可能局部会发热，转子便弓形。

RBF=转子条 X 转频

2xLF=2 倍线频（100 或 120Hz）

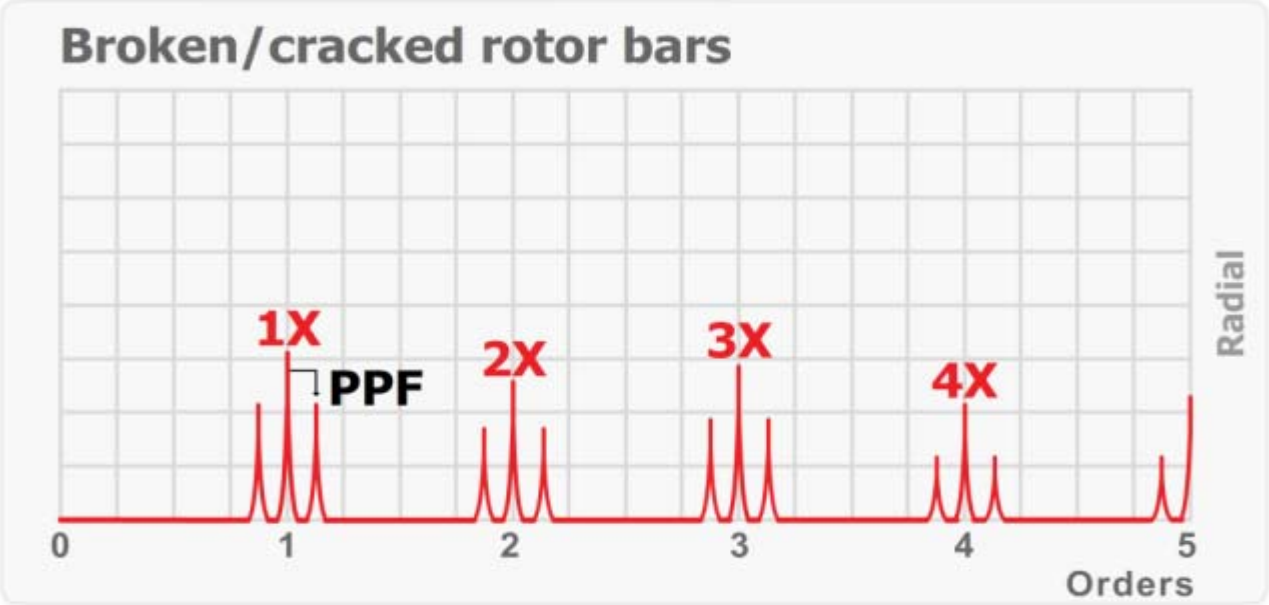
请查看 I 型和 II 型转子故障。

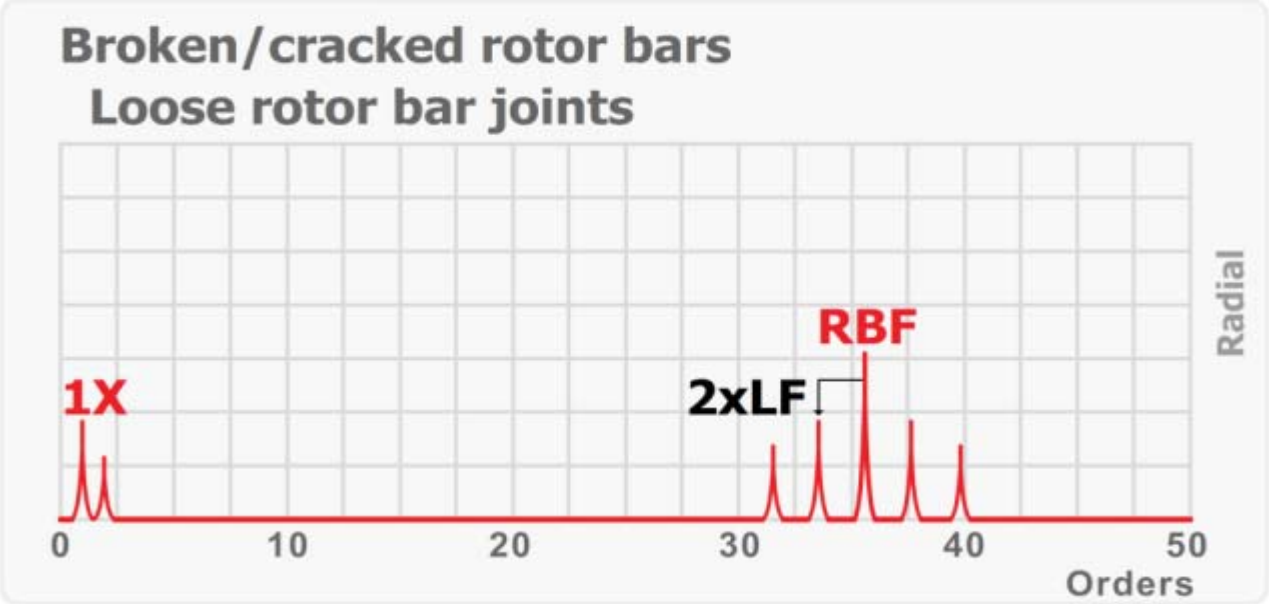
频谱：I 型：需要高分辨率频谱。Y 轴采用对数坐标，会有帮助。

II 型：分析频率需要足够高，以便查看 RBF 和 2X 线频，2XRBF 可能出现（这是常见特征，并一定表示出现故障，幅值变大时需注意）。

时域波形：I 型：最少 10s 的波形，会显示拍振。听下拍振的振动。

电机电流分析：使用电流钳，采集线频（50 或 60）附近的高分辨率频谱。当查看线频峰值和极通过频率的差值时，采用对数谱。





13.6 Induction motors: Loose rotor bars 异步电机：转子条松动

Symptoms: 100/120 Hz sidebands around rotor bar pass frequency 特征：转子条通过频率±100/120 Hz

If there are loose rotor bars there will be a peak at the rotor bar pass frequency (RBF - the number of rotor bars times the turning

如果转子条发生松动，会有转子条通过频率及 100/120 Hz 边带（RBF=转子条

speed), with sidebands of twice line frequency (100 or 120 Hz). Even if you do not know the number of rotor bars, if you see a high frequency with twice line frequency sidebands, you can be somewhat confident that this fault condition exists.

Please note that it is quite common to see this pattern. You should only investigate further if these peaks change in amplitude.

Rotor bar pass frequency (RBF) = Number of rotor bars X Running speed

2xLF = Twice line frequency (100 or 120 Hz)

Spectrum analysis: Look for the peaks at RBF plus and minus 2xLF. Note that sometimes you will see a high peak of RBF + 2xLF whereas the peak at RBF and RBF – 2xLF may be quite small.

Please note that it is quite common to see this pattern. You should only investigate further if these peaks change in amplitude.

Rotor bar pass frequency (RBF) = Number of rotor bars X Running speed

2xLF = Twice line frequency (100 or 120 Hz)

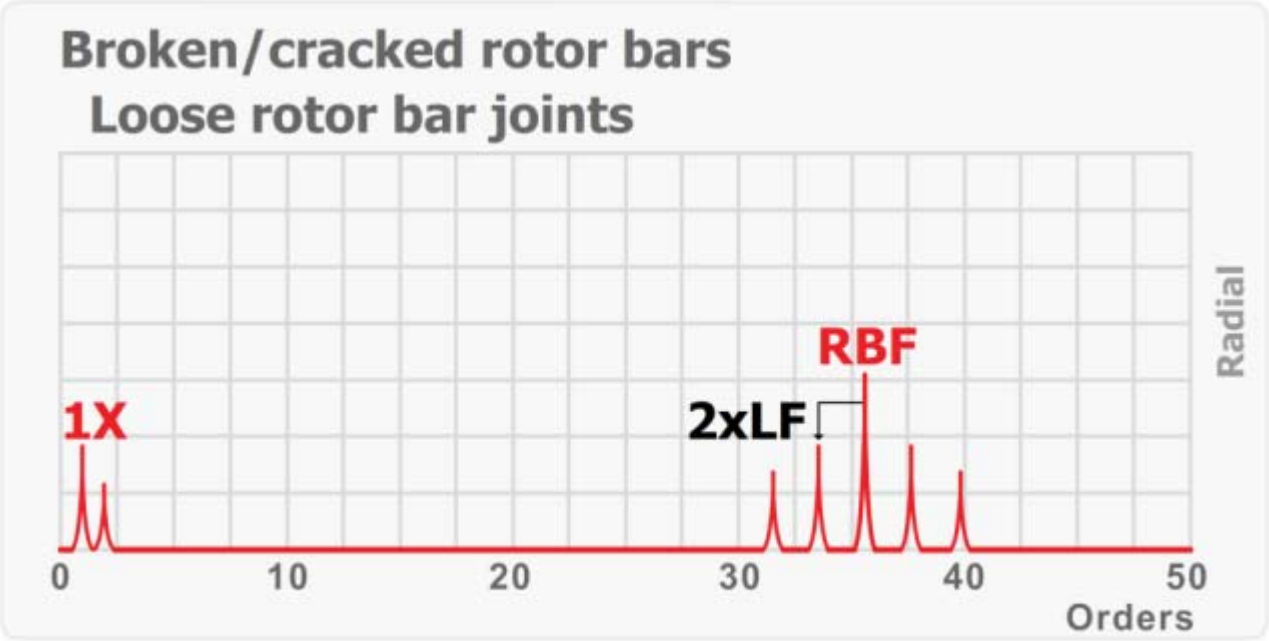
X 转频）。即使你不知道转子条条数，如果你看到某个高频有 2X 线频边带，也可以确认，这种故障存在。

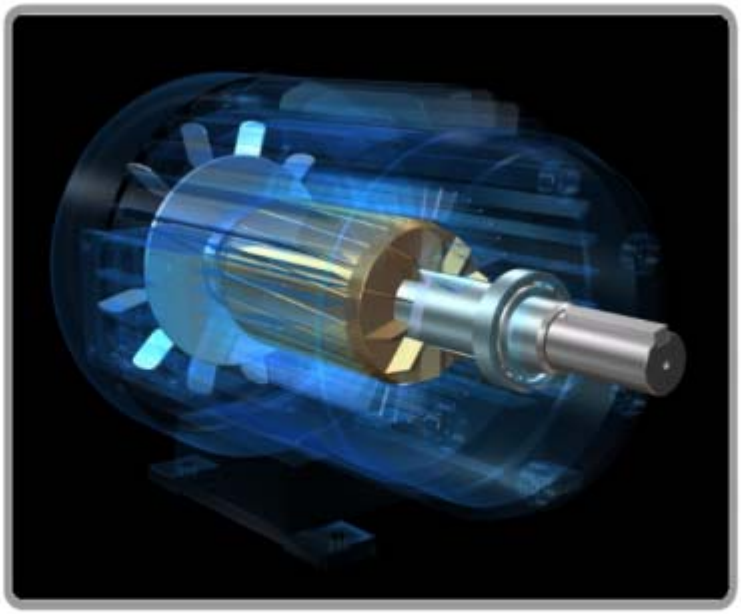
请注意，这种特征很常见，只有幅值发生变化了，才需进一步注意。

转子条通过频率（RBF）=转子条 X 转频

2xLF=2 倍线频（100 或 120Hz）

频谱： 查看 RBF±2X 线频。需要注意的是，有时你会看到 RBF +2X 线频的幅值很高，而 RBF -2X 线频的幅值很低。





13.7 Induction motors: Loose rotor 异步电机：转子松动

Symptoms: High 1X and harmonics 特征：1X 及谐频幅值高

Sometimes the rotor can slip on the shaft, usually intermittently depending on temperature, and this causes severe

通常随温度变化，转子电枢会在转轴上间歇性松动，会导致 1X 及谐频振动大。

vibration at 1X and harmonics. Abrupt changes in load or line voltage can instigate this condition.

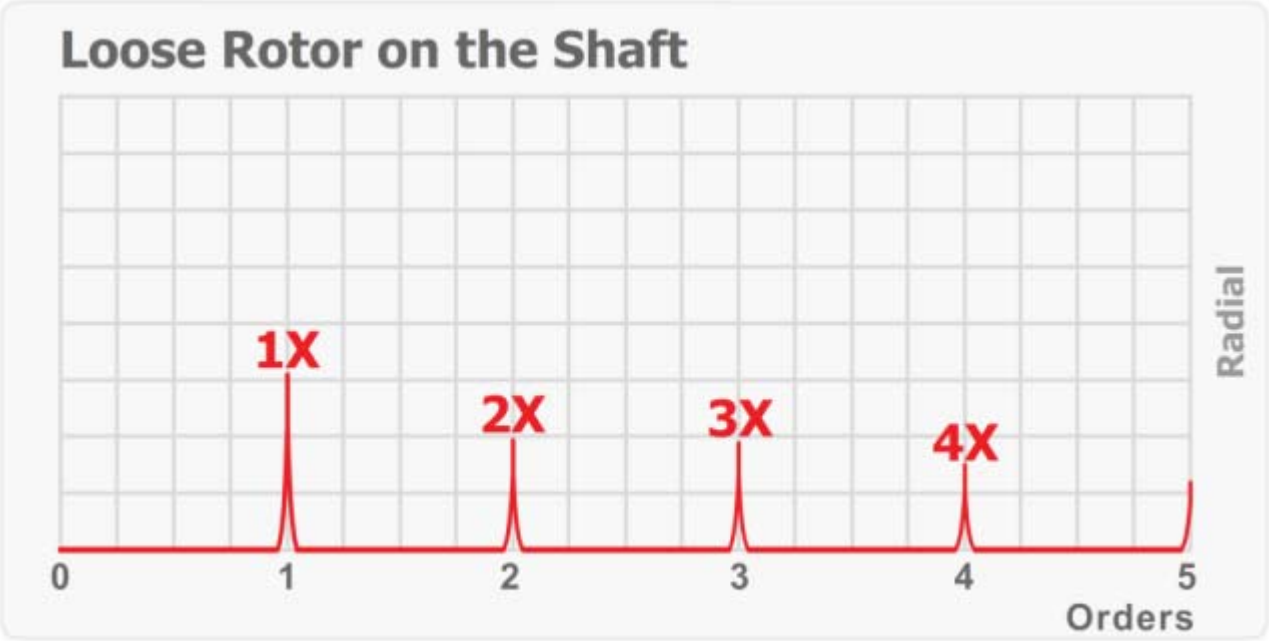
负载和电压突然变化会加重这种故障。

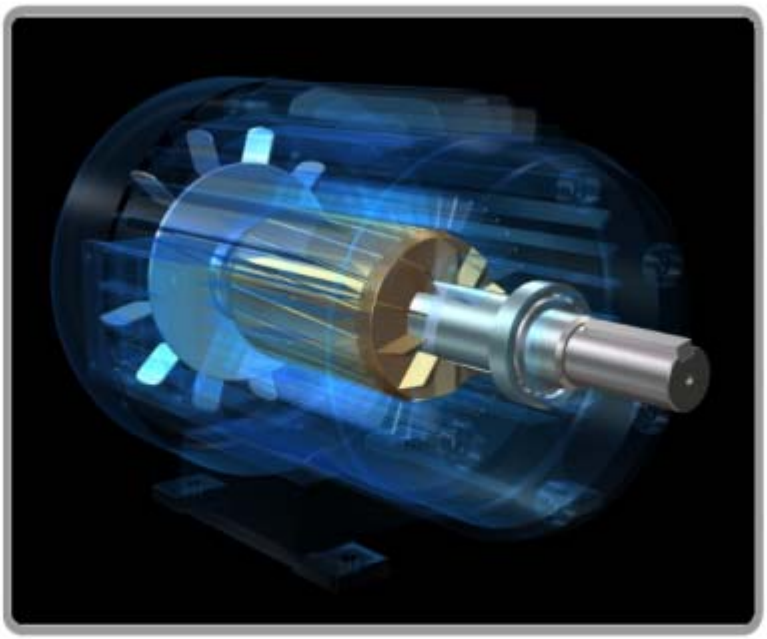
Spectrum: Look for the harmonics, however you need to be sure not to confuse the condition with rotating looseness. If the fault is intermittent then it may be present in one spectrum and not in another, and it may also depend on the operation condition (temperature) of the motor.

频谱：查看 1X 及谐频，但是不要与松动混淆。如果故障时间隙性的，那么可能在这个频谱出现而另一个不出现。当然也取决于电机操作条件（温度）。

Time waveform: Look for signs of the looseness and sliding motion, and look for signs that the fault may be intermittent. If you have a time waveform with a time base of 30 seconds or longer you may see the vibration change substantially during that time.

时域波形：查看松动和间歇性的特征。如果波形时间 30s 或更长，会看到振动变化。





13.8 Induction motors: Loose stator windings 异步电机：定子绕组松动

Symptoms: High 100/120 Hz radial 特征：100/120 Hz 径向幅值高

If the electrical windings of the motor stator are even a little loose, the vibration level at twice line frequency will be increased. This

若电机的定子绕组有点松动，那么 2X 线频幅值会变大。因为它会磨损绕组的

condition is very destructive because it abrades the insulation on the wire, leading to shorted turns and eventual short circuits to ground and stator failure.

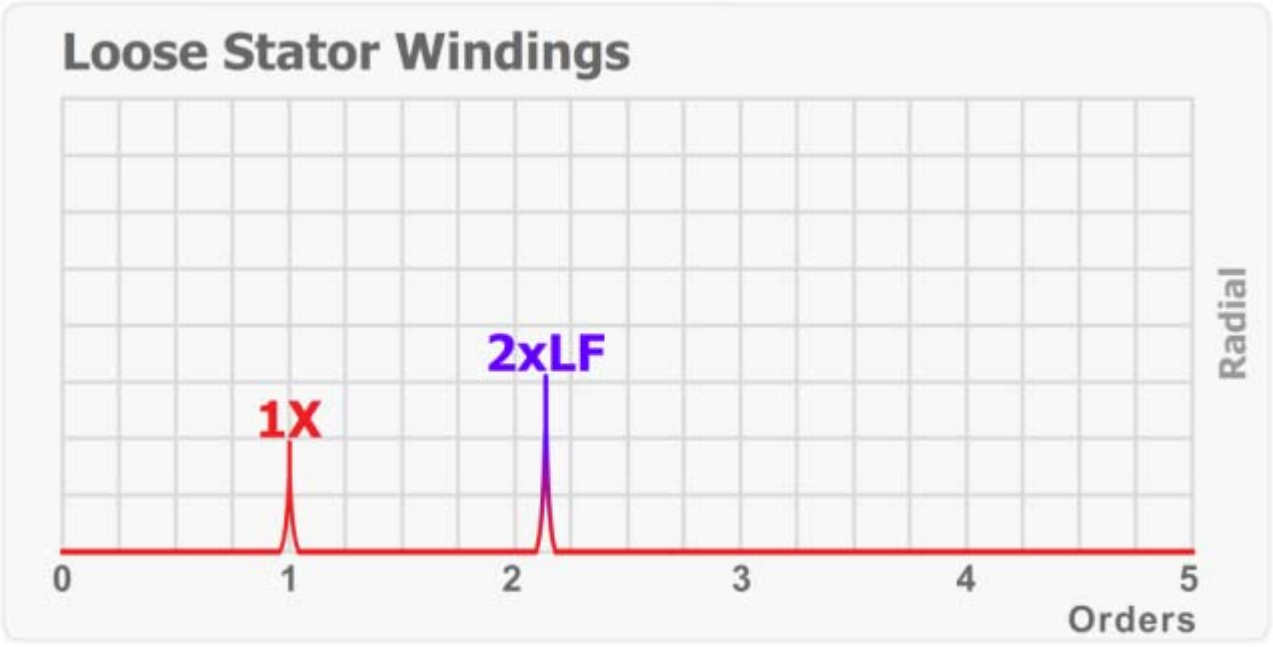
绝缘，导致匝间短路和最终接地短路和定子故障。所以这种故障是非常有破坏性的。

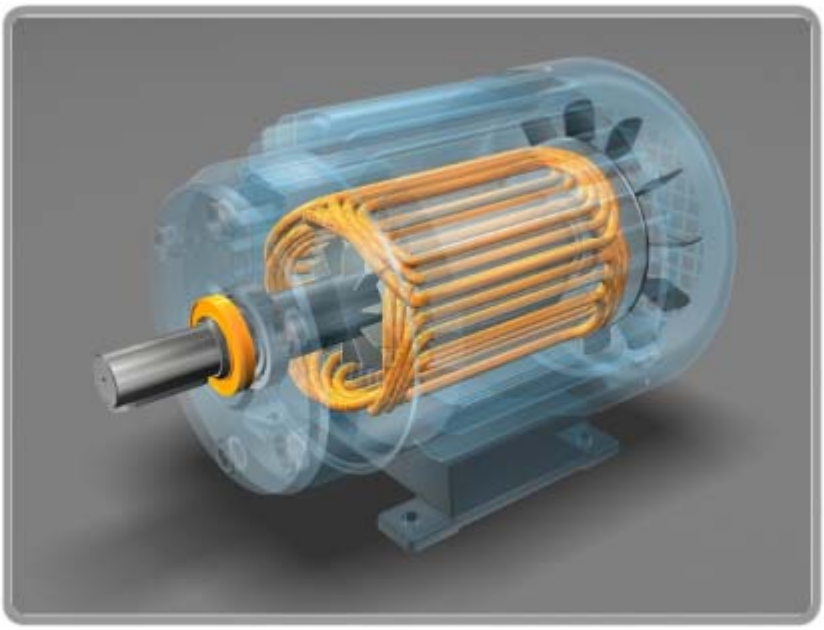
The 2xLF vibration will either be 100 Hz or 120 Hz, depending upon where you are in the world. This source of vibration is due to "magnetostriction".

2X 线频振动（100Hz 或 120Hz），振动源是“磁致伸缩”

Spectrum: Look for the high 2xLF (100 or 120 Hz) peak. In a two-pole motor there could be a 2X peak and therefore there will be beating between the 2X and 2xLF sources on vibration.

频谱：查看 2X 线频幅值。2 级电机，2X 转频和 2X 线频会有拍振。





13.9 Induction motors: Shorted laminations 异步电机：铁芯短路

Symptoms: High 100/120 Hz radial100/120 Hz 径向幅值高

The rotor and stator of AC motors are made of thin laminations that are isolated from each other. If the laminations are shorted

交流电机的转子和定子是由相互绝缘隔离的硅钢片叠压而成。如果硅钢片短路

together, local heating and resultant thermal warping will occur.

Shorted laminations also cause higher twice line frequency vibration levels. The warping can cause the 1X level to increase, and often pole pass sidebands are observed.

The pole pass frequency is the slip frequency times the number of poles. The slip frequency is the difference between the actual RPM and the synchronous speed.

Spectrum: Look for a large peak at 2xLF (100 Hz or 120 Hz), plus look for pole pass sidebands around 1X. You will need a high resolution spectrum. A log y-axis scale will also help you to detect the pole pass sidebands.

Waveform: The modulation (pole pass frequency) should be visible in the waveform, however because it is a low frequency you need to have a waveform with a time base of 15 seconds minimum.

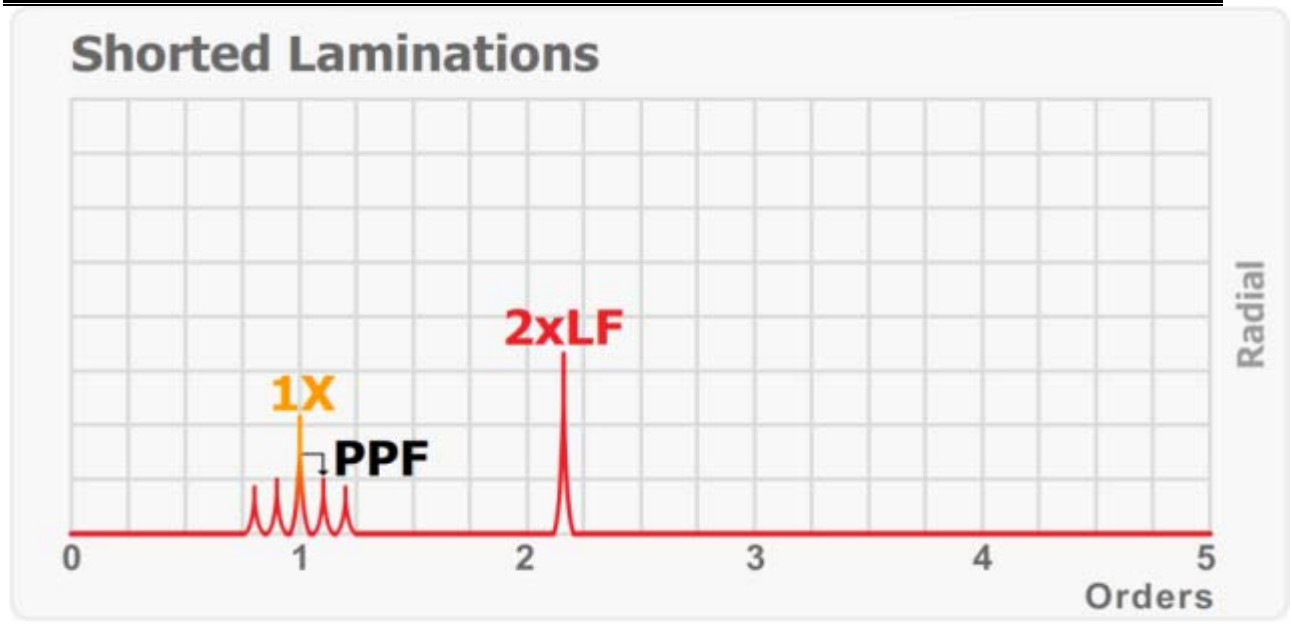
会发生局部发热，导致热变形。

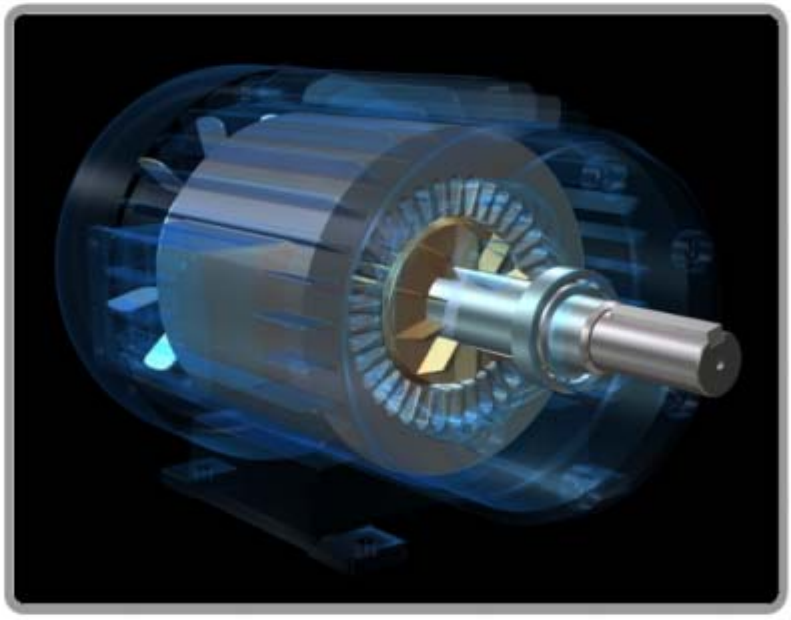
硅钢片短路会导致 2X 线频幅值高，热变形会导致 1X 幅值变大，常常会看到极通过频率边带。

极通过频率是滑差频率乘以级数。滑差频率是实际转速和同步转速直接的差值。

频谱：查看 2X 线频幅值和 1X 及极通过频率边带。需要高分辨率，Y 轴对数坐标会帮你发现极通过频率边带。

时域波形：由于低频，波形时间最少 15s，会看到波形（极通过频率）调制。





13.10 Induction motors: Loose connections 异步电机：接头松动

Symptoms: High 100/120 Hz with 33/40 Hz sidebands 特征：100/120 Hz 及 33/40 边带

Phasing problems due to loose connectors can cause excessive vibration at twice line frequency (100 or 120 Hz), with sidebands

接头松动，会造成失相故障。导致 2X 线频(100 或 120 Hz)振动大且有 1/3 线频

of one-third line frequency (16.66 Hz or 20 Hz). The modulation (one-third line frequency) is because we have lost one of the three phases, thus the magnetic force of twice-line frequency rises and falls at one-third of the running speed.

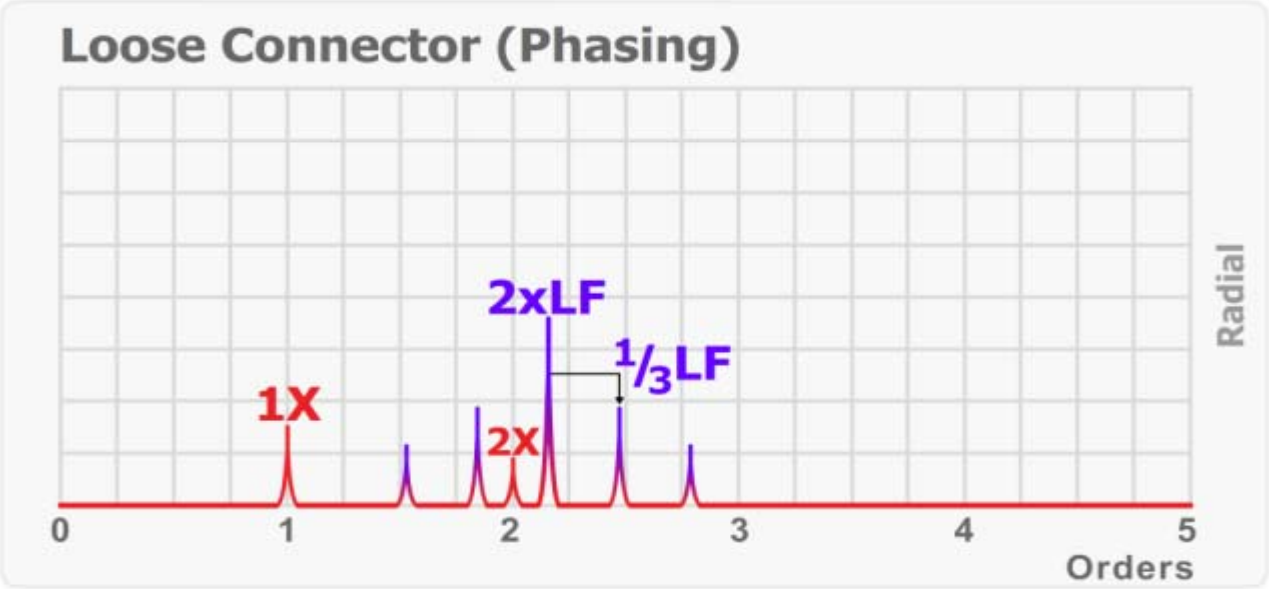
边带（16.66 Hz 或 20 Hz）。由于失去了三相中的一相，所以发生调制（1/3 线频）。

Spectrum: Look for a high 2xLF (100 Hz or120 Hz) peak with dominant sidebands of one-third line frequency (16.66 Hz or 20 Hz).

频谱：查看 2X 线频幅值及 1/3 线频（16.66 Hz 或 20 Hz）边带。

Time waveform: The time waveform should also rise and fall due to the modulation. Because the modulating frequency is 16.66 Hz or 20 Hz, the rise and fall will take 0.06 seconds (1/16.66 Hz) or 0.05 seconds (1/20 Hz). Therefore if the time base is more than 1 second there will be too many pulsations to be able to see the modulation.

时域波形：由于调制，波形会上升和下降。由于调制频率是 16.66 Hz 或 20 Hz，上升和下降所有的时间为 0.06s 或 0.05s.如果波形长度 1s 以上，会看到很多脉冲，能看到调制现象。



14 Synchronous motors: Loose stator coils 同步电机：定子线圈松动

Symptoms: High coil passing frequency with possible 1X sidebands 特征：线圈通过频率及可能的 1X 边带

If the coils in a synchronous motor are loose there will be elevated vibration at the coil passing frequency (CPF).>. There will also

如果同步电机的线圈松动，那么线圈通过频率（CPF）的幅值会变大。也可能

likely be modulation of the running speed, therefore there will be 1X sidebands around the CPF peak.

被转频调制，所以 CPF 可能会有 1X 边带。

Spectrum: Look for the elevated coil passing frequency peak with 1X sidebands. You will need to ensure that the Fmax will allow you to see this peak with adequate resolution to see the sidebands.

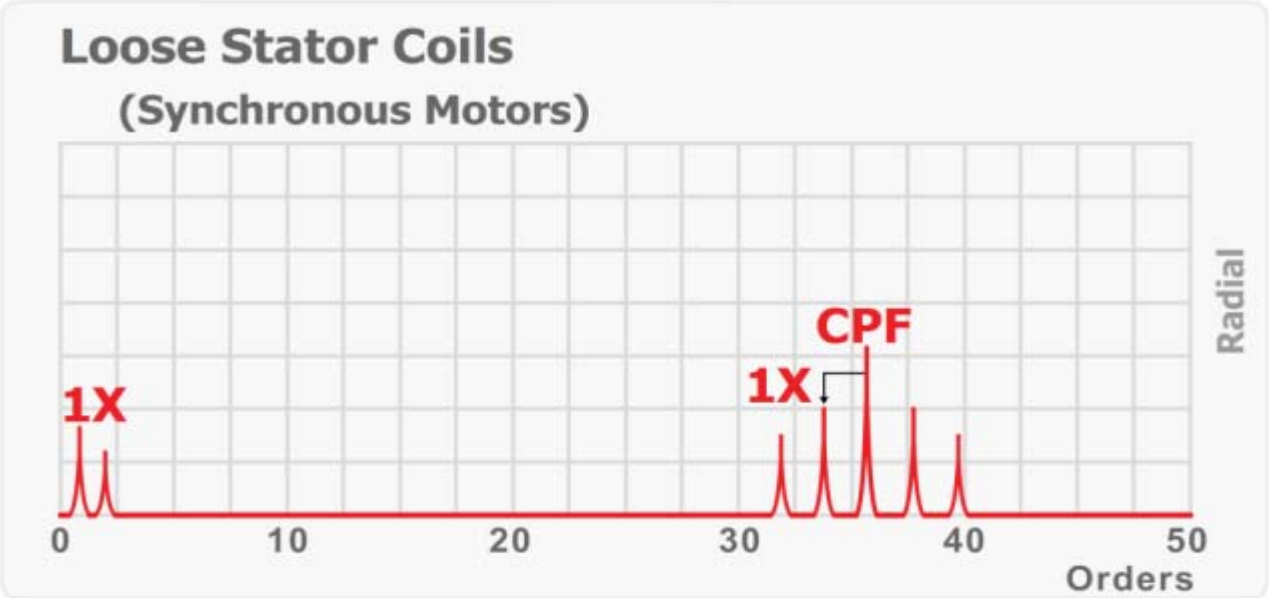
频谱：查看线圈通过频率及边带。分析频率需要足够大以便 CPF，分辨率足够的以便查看边带。

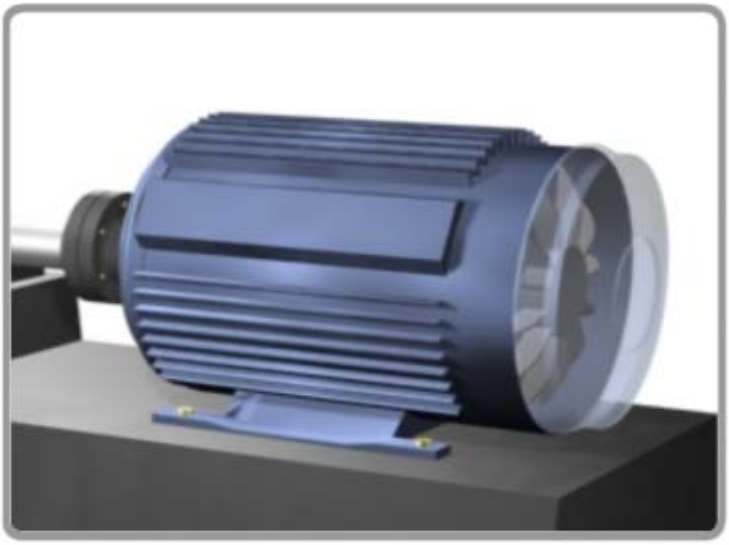
Time waveform: If the vibration is modulated by 1X turning speed you should see the vibration amplitude rise and fall with a period equal to the turning speed. Therefore the time base of the waveform should equal 6-15 shaft cycles.

时域波形：如果被 1X 转频调制，会看到振动幅值上升和下降周期等于转速周期。波形时间长度应该取 6-15 周。

CPF = Number of stator coils times the motor RPM

CPF=定子线圈条数 X 转速





15 DC motors: General fault comment 直流电机：常见故障说明

Symptoms: Line frequency harmonics or fractional SCR firing frequency peaks 特征：线频谐频或 SCR 亚倍频

In a normal spectrum from a DC motor there should not be a strong line frequency (50 Hz

直流电机正常频谱中不会有很大的线频

or 60 Hz) peak and there should be no harmonics. Likewise it is expected that there will be a peak at the SCR firing frequency, but there should be no sidebands, no harmonics and no sub-harmonics (1/3xSCR or 2/3xSCR). The presence of these peaks indicates a fault in the SCR circuit or in the armature (rotor) or commutator.

Please see the named fault conditions for more information.

Spectrum: Spectrum analysis is the best tool to detect the peaks at the frequencies named.

Time waveform: If there is a phase loss, a tuning problem, or any other fault that changes the vibration or generates modulation, the time waveform will be a useful graph to analyze.

- SCR = 3xLF if half-wave rectification or 6xLF if full-wave rectification
- LF = 50 Hz or 60 Hz

幅值及其谐频，同样会有 SCR 频率，但是不会有边带、谐频和亚倍频（1/3xSCR 或 2/3xSCR）。这些峰值出现说明 SCR 电路或转子电枢或换向器故障。

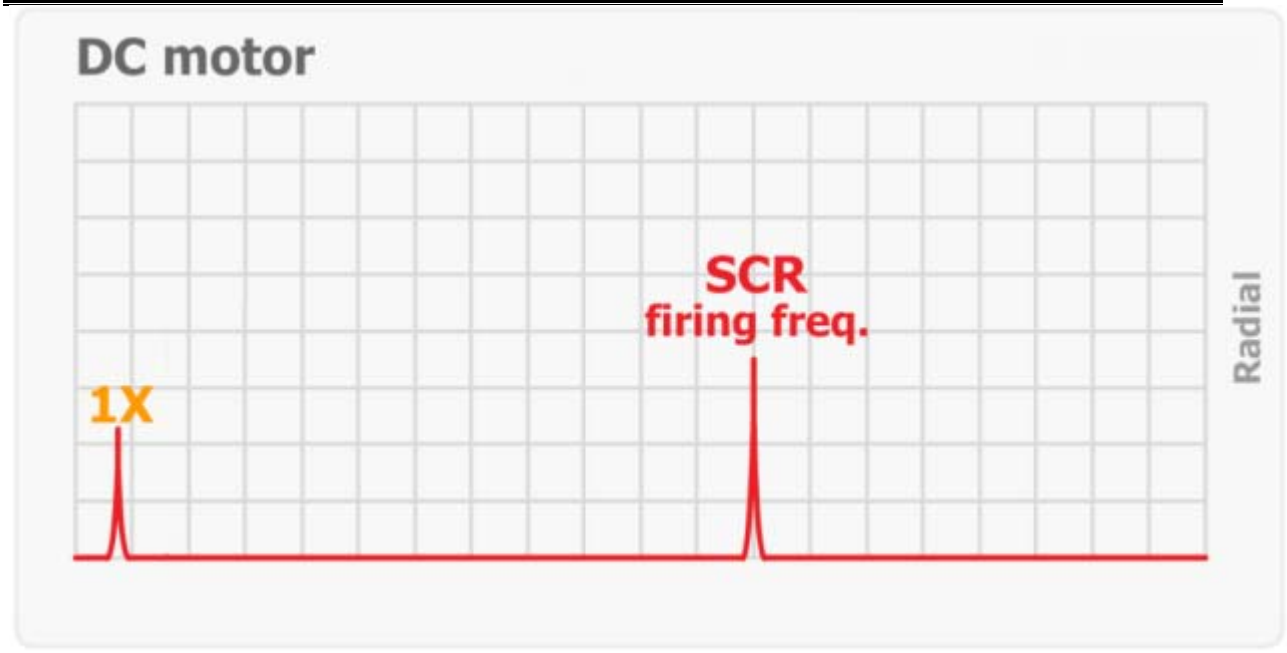
该故障，请查看请其它章节

频谱：频谱分析是检测这些峰值的最有用工具。

时域波形：如果发生缺项，调频或其它故障，而改变了振动模式或产生调制。时域波形是有用的。

SCR=3XLF（半波整流）或 6XLF（全波整流）

LF=50 或 60Hz



15.1 DC motors: Grounding fault 直流电机：接地故障

Symptoms: Line frequency peak (50 Hz or 60 Hz)特征：线频（50 或 60Hz）

In a normal spectrum from a DC motor there should not be a strong line frequency (50 Hz or 60 Hz) peak. If the LF peak does increase

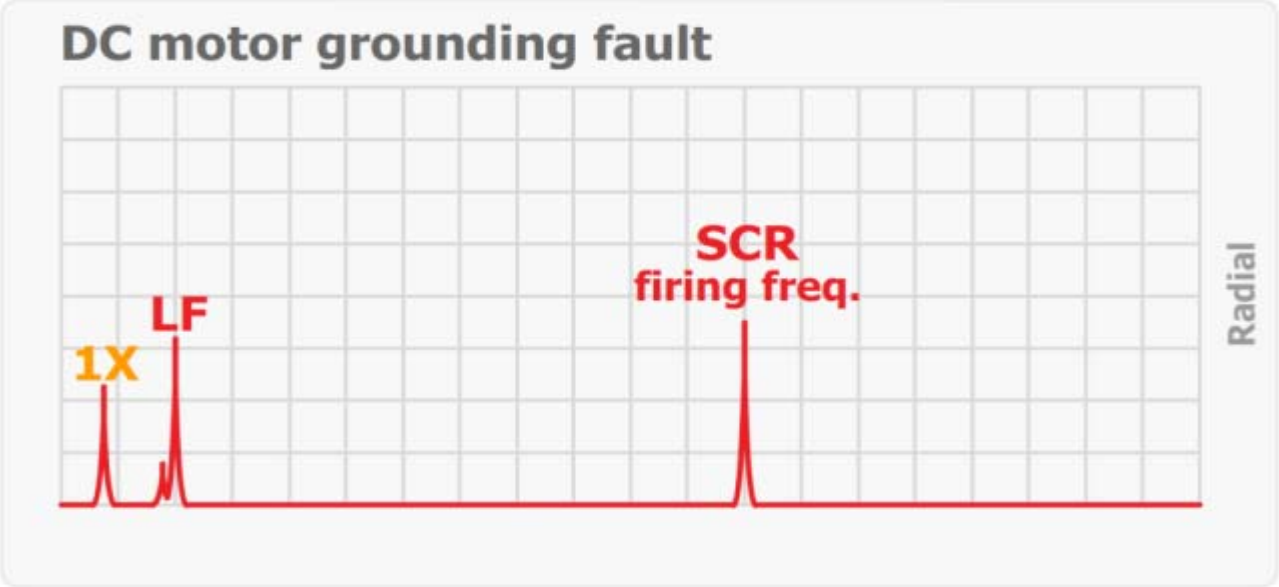
直流电机正常频谱中不会有很大的线频

in amplitude then grounding should be suspected.

Grounding can occur when there are broken armature (rotor) windings. If the commutator "pads" or "rises" are not correctly bonded to the armature then again you will see the 50 Hz or 60 Hz peak.

幅值。如果线频幅值变大，则接地可能有问题。

转子电枢绕组开裂造成绕组接地。如果换向器和电枢连接不能正常动作，那么你会看到 50 或 60Hz 峰值。



15.2 DC motors: SCR Tuning faults 直流电机：SCR 调频故障

Symptoms: 1X sidebands around 1XSCR and 2XSCR firing frequencies 特征：

1XSCR 和 2XSCR 会有 1X 边带

If there is a tuning problem in the SCR then the vibration amplitude will rise and fall once per shaft revolution. In a normal spectrum from a DC motor it is expected that there will be a peak at the SCR firing frequency. However if there is a peak at 2xSCR and there are 1X sidebands then you should suspect that there is a tuning fault.

如果 SCR 调频发生故障，那么振动幅值就会在转子每旋转一周内上升和下降。直流电机正常的频谱会有 SCR 频率。但是如果出现 2XSCR 和 1X 边带，你就应该怀疑出现调频故障。

The SCR firing frequency depends upon whether your system using full wave rectification (6xLF) or half-wave rectification (3xLF) where LF is the line frequency (50 Hz or 60 Hz).

SCR 频率取决于系统全波整流还是半波整流。

Spectrum: Look for a peak at 1XSCR and 2xSCR firing frequency with 1X turning speed sidebands.

频率：查看 1XSCR 和 2XSCR 及 1X 边带

Time waveform: Look for the modulation at the turning speed (1X) of the motor – the amplitude will rise and fall. Ideally you should have between 6 and 15 cycles of shaft rotating in the time waveform so that you can see the rise and fall in amplitude.

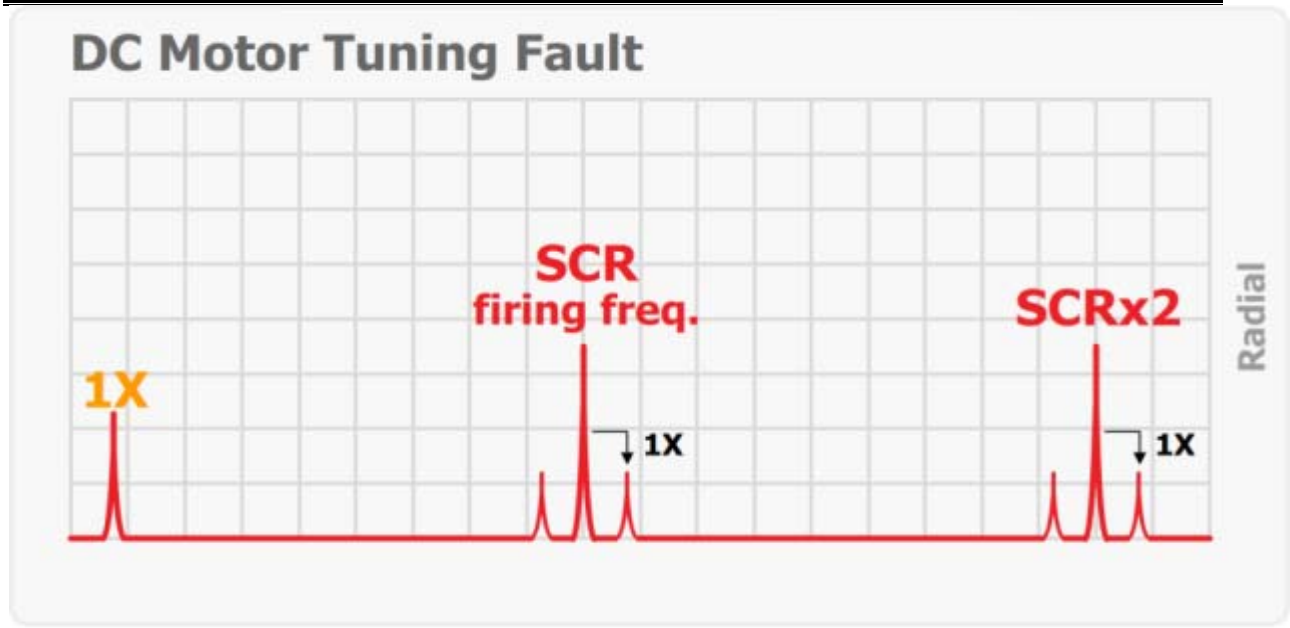
时域波形：波形长度最好在 6-15 周，很容易看到 1X 转频调制，幅值会上下波动。

SCR = 3xLF if half-wave rectification or 6xLF if full-wave rectification

SCR=3XLF（半波整流）或 6XLF（全波整流）

LF = 50 Hz or 60 Hz

LF=50 或 60Hz



15.3 DC motors: Phase loss 直流电机：缺相

Symptoms: 1/3xSCR, 2/3xSCR and SCR peaks visible 特征：1/3xSCR, 2/3xSCR，SCR 峰值

A phase can be lost due to a fuse related problem, or a shorted or failed firing card.

当保险丝或触发板故障，就会缺相，频

The spectrum will contain peaks at 1/3 the SCR firing frequency and 2/3 firing frequency.

The SCR firing frequency depends upon whether your system using full wave rectification (6xLF) or half-wave rectification (3xLF) where LF is the line frequency (50 Hz or 60 Hz). When a phase is lost the peaks will appear at 1/3xSCR and 2/3xSCR regardless of whether it is full wave rectified or half-wave rectified.

Spectrum: Look for a peak at 1/3xSCR, 2/3xSCR and 1xSCR.

Time waveform: The vibration pattern will show that there are only two phases being rectified.

SCR = 3xLF if half-wave rectification or 6xLF if full-wave rectification

LF = 50 Hz or 60 Hz

谱中会有 1/3xSCR, 2/3xSCR 峰值。

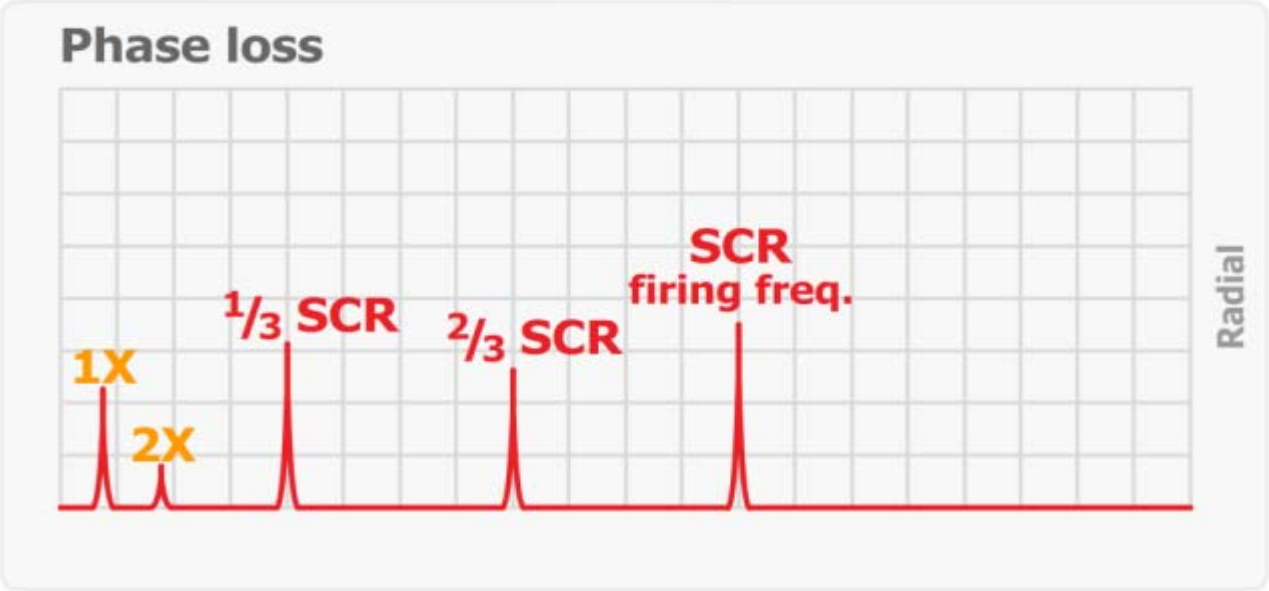
SCR 频率取决于系统全波整流还是半波整流。当缺相时，不敢全波整流还是半波整流，都会出现 1/3xSCR and 2/3xSCR。

频谱：查看 1/3xSCR, 2/3xSCR 和 1xSCR。

时域波形：振动模式会显示只有两相整流。

SCR=3XLF（半波整流）或 6XLF（全波整流）

LF=50 或 60Hz



15.4 DC motors: Loose connectors, shorted control card and more 直流电机：接头松动，控制卡短路

Symptoms: Harmonics of the line frequency (50 Hz or 60 Hz)特征：线频(50 Hz 或 60 Hz)谐频

A variety of faults can cause harmonics of the line frequency (50 Hz or 60 Hz) to

各种故障会导致出现线频的谐频。

appear. These faults include loose connectors, shorted control card, fuse problems or a failed firing card.

这些故障有：接头松动、控制卡短路、保险丝故障、触发版故障。

Harmonics of line frequency are not normal and do indicate that a fault exists.

线频的谐频不正常，说明有故障存在。

Spectrum: Look for a peak at LF, 2xLF, 3xLF etc. The number of harmonics witnessed will depend upon whether the system is half-wave rectified or full wave rectified. In a system that uses full-wave rectification it is common for the LF and 5xLF peal to be highest.

频谱：查看 1X 线频、2X 线频，3X 线频等。谐频的数量系统全波整流还是半波整流。对于全波整流，1X 线频和 5X 线频会很高。

SCR = 3xLF if half-wave rectification or 6xLF if full-wave rectification

SCR=3XLF（半波整流）或 6XLF（全波整流）

LF = 50 Hz or 60 Hz

LF=50 或 60Hz

15.5 DC motors: DC motor hunting 直流电机速度偏差

Symptoms: Sidebands around SCR firing frequency 特征：SCR 频率有边带

If there is a fault in the speed comparator card (circuit) the speed of the drive will not be constant – it will fluctuate by a small

如果速度比较卡（回路）出现故障，电机转速会小幅波动。

RPM amount. As a result you may see that the 1Xpeak in the spectrum is broader and lower than normal (if the speed varies while the spectrum is collected), and you will see sidebands around the SCR firing frequency peak. The sidebands will be separated by the amount that the RPM is varying.

结果你能看到 1X 峰值变宽，幅值比正常低（当速度变化时，采集频谱），也会看到 SCR 频率及边带。边带有转速变化量决定。

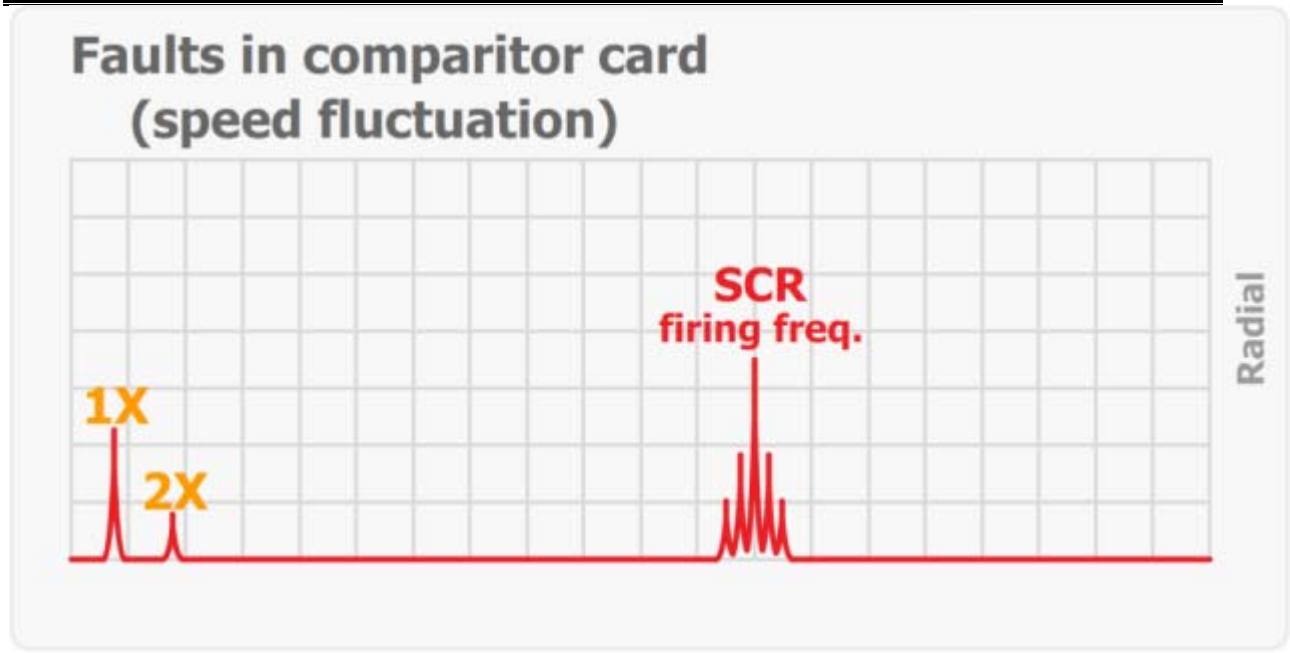
Spectrum: A high resolution spectrum will be required to see the sidebands. Changing the number of averages will change the amplitude and shape of the 1X peak – with more averages the peak will smear more (broader and lower amplitude). If you can look at a live high resolution spectrum and graphically zoom in on the 1X peak you may see the peak moving higher and lower in frequency.

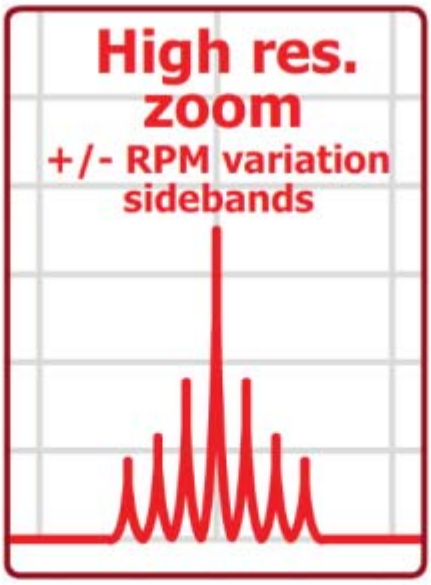
频谱：高分辨才能看清边带。改变平均次数会改变 1X 幅值和形状，平均越多，峰值越低（变宽变低）。如果采用实时高分辨率频谱，并放大 1X，你会看到峰 1X 值高低移动。

- SCR = 3xLF if half-wave rectification or 6xLF if full-wave rectification
- LF = 50 Hz or 60 Hz

SCR=3XLF（半波整流）或 6XLF（全波整流）

LF=50 或 60Hz





16 Gearbox: Gear mesh 齿轮：啮合频率

Symptoms: High gearmesh (number of teeth times running speed)特征：齿轮啮合频率幅值高

It is common to witness a peak at the gearmesh frequency. However, if the amplitude of the peak increases, or harmonics develop, or the sidebands of the input or output speed grow in amplitude, then it is highly likely that a fault is developing in the gearbox.

GMF 频率出现很正常。如果其幅值或谐波幅值增长，又或两侧边带幅值增长，那么齿轮故障很有可能正在发展。

It is up to you what to do next. If you carefully analyze the spectrum and analyze a time waveform (that has been measured correctly) it is possible to pinpoint the fault condition.

These frequencies will be most prominent in the radial direction for spur gears, and in the axial direction for helical gears.

对于直齿轮，这些频率会在径向占主导，对于斜齿轮，这些频率会在轴向占主导。

Gear mesh = Number of teeth x Shaft speed

GMF=齿数 X 轴转速

Output speed = Input speed x Input teeth/Output teeth

输出转速=输入转速 X 输入齿轮齿数/输出齿轮齿数

Spectrum: Your Fmax should be set to equal or exceed approximately 3.3 times the gearmesh frequency in order to view up to 3xGMF its sidebands. However you also need enough resolution to be able to clearly see the sidebands.

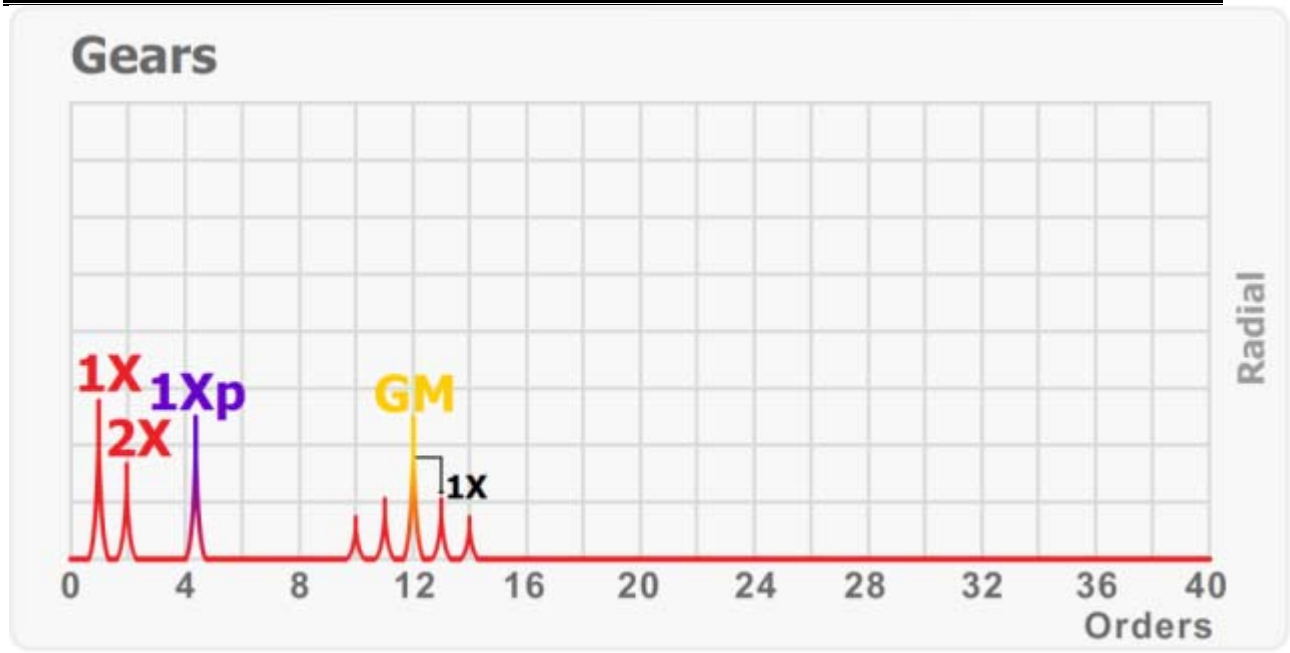
频谱分析频率设置：为了分析 3XGMF 及其边带，分析频率设置为 3.3XGMF。分辨率不能太低，要能看清楚边带，分析线数也要合适。

Time waveform: TWA is your best tool for detecting and diagnosing gearbox faults. You need to ensure, however, that you can see a sufficient number of gear rotations, and have the resolution to see each individual tooth mesh.

时域波形：能很有效的诊断轴承故障。设置合理的时间和分辨率。

Wear particle analysis: WPA is an excellent tool for the early detection of many gear faults.

磨粒分析：能够早期发现轴承故障。



16.1 Gearbox: Tooth wear 齿轮：齿轮磨损

Symptoms: 1X sidebands around the gearmesh frequency 特征：GMF 有 1X 边带

When teeth begin to wear, two things will happen. First the sidebands of gear mesh will increase in amplitude. The sidebands

当齿轮开始磨损，会出现两个征兆。1、GMF 边带的幅值会增长。该边带就是对

will correspond to the speed of the gear that is worn.

Second, the natural frequency of the gear is excited. This peak will also exhibit sidebands, and as a natural frequency, it is likely to have a broader base.

Gear mesh = Number of teeth x Shaft speed

Output speed = Input speed x Input teeth/Output teeth

Spectrum: The key sign is an increase in sidebands – the number of sidebands and their amplitude. 3xGMF will often increase in amplitude.

Time waveform: There will be increased modulation of the gear mesh frequency which will be visible in the waveform.

Wear particle analysis: WPA is an excellent tool as it will warn you about the increase in particle count and through a study of the size, shape, composition and color of the particles.

应磨损齿轮的转频。

2、会激起齿轮固有频率 Gnf。Gnf 两侧也会有边带，很有可能会有底部噪声。

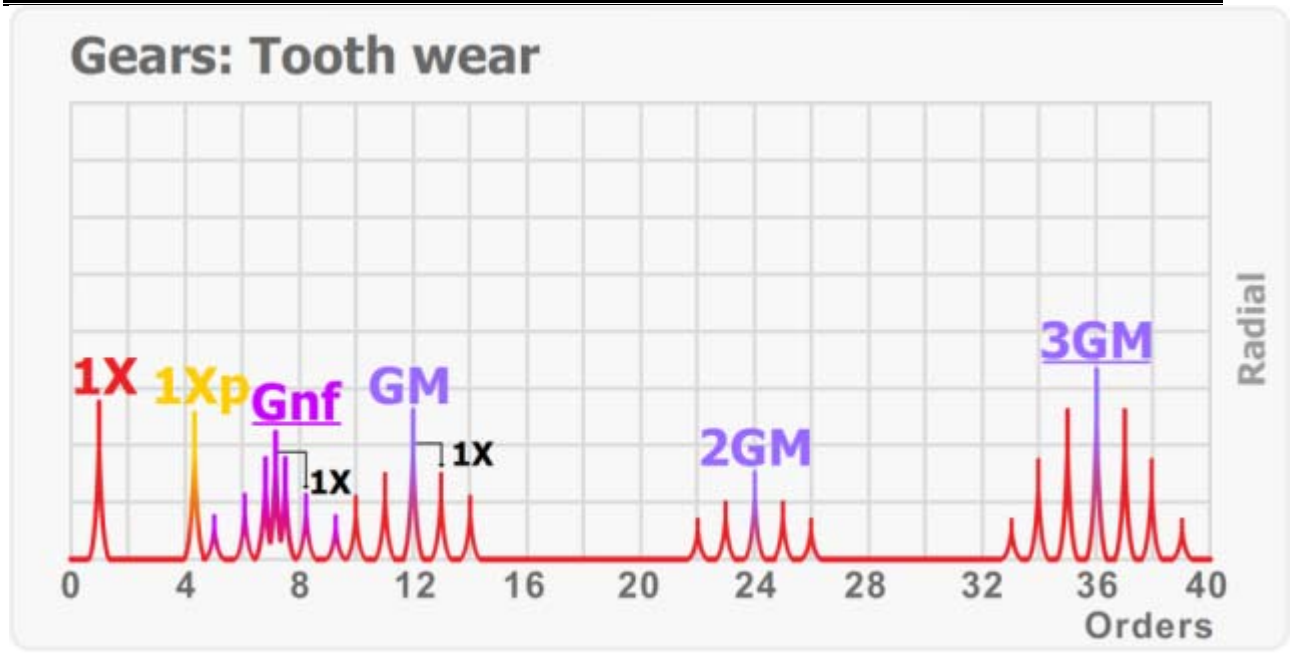
GMF=齿数 X 轴转速

输出转速=输入转速 X 输入齿轮齿数/输出齿轮齿数

频谱：关键是边带增长-幅值增长和边带谐频数量增长。3XGMF 幅值通常也会增长。

时域波形：GMF 调制越来越明显。

磨粒分析：磨粒的大小、形状、组成、颜色等理化指标进行判断。



16.2 Gearbox: Tooth load 齿轮：齿轮过载

Symptoms: High gearmesh frequency 特征：GMF 幅值高

The level of the tooth mesh frequency is dependent on the alignment of the shafts carrying the gears, and the load on the gear.

1XGMF 的幅值取决于齿轮负载，两根齿轴的对中情况。1XGMF 幅值过高不

A high peak at the gear mesh frequency does not necessarily indicate a problem, however an increase in amplitude without an increase in sidebands or harmonics suggests that tooth load has increased.

Gear mesh = Number of teeth x Shaft speed

Output speed = Input speed x Input teeth/Output teeth

Symptoms: High gearmesh frequency

Spectrum: The key sign is an increase in the gear mesh peak. There will not necessarily be a change in harmonics of gear mesh or sidebands.

Time waveform: The gearmesh frequency vibration will increase in vibration which should be visible in the waveform.

Wear particle analysis: Unless wear occurs, oil analysis and wear particle analysis will not reveal this condition.

一定是故障。如果边带和谐波的幅值都没有增长，那表明齿轮负载在增加。

GMF=齿数 X 轴转速

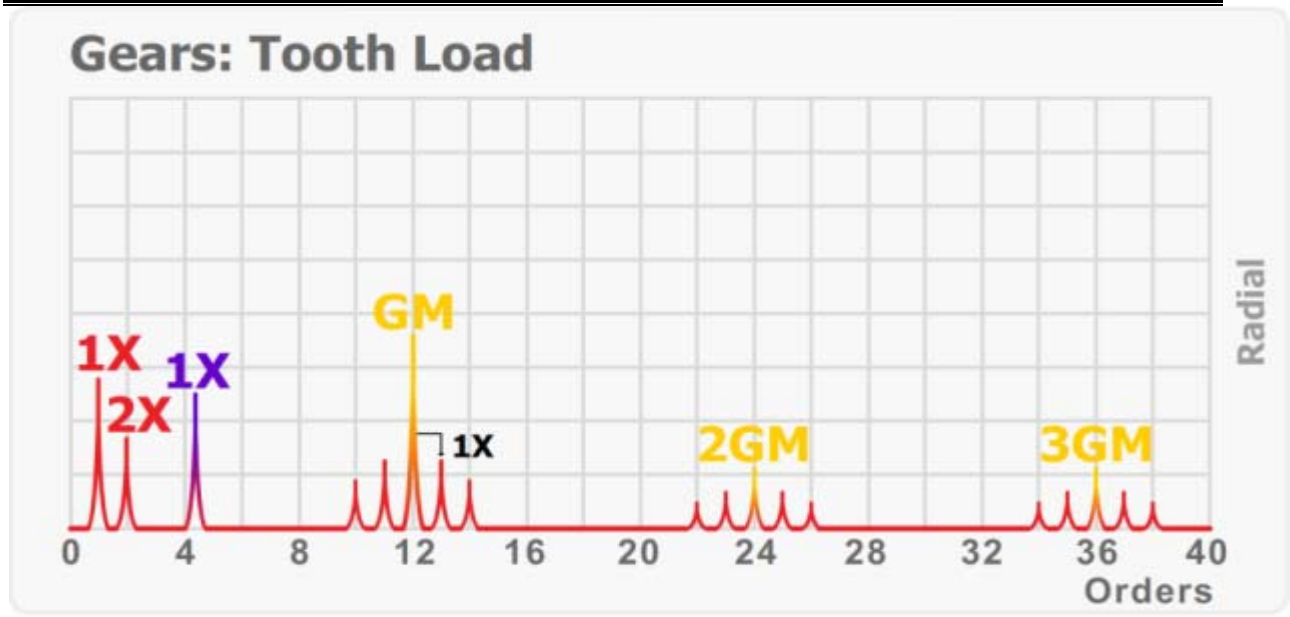
输出转速=输入转速 X 输入齿轮齿数/输出齿轮齿数

特征：GMF 幅值高

频谱：关键是 1XGMF 幅值，这里不一定是 GMF 谐频和边带的变化。

时域波形：GMF 幅值增长能在时域波形中看到。

磨粒分析：除非发生磨损，油液分析和磨粒分析不能发现此故障。



16.3 Gearbox: Eccentric gears 齿轮：偏心齿轮

Symptoms: 1X sideband around the gearmesh frequencyGMF 特征：GMF 有 1X 边带

If a gear is eccentric (or the shaft is bent), there will be an increase in the amplitude of the sidebands around the gear mesh

如果齿轮是偏心的（或转轴是弯的），那么 GMF±1X 的幅值会增长。可能

frequency. The key is that rather than witnessing a family of sidebands, there may only be one dominant sideband on either side of the gear mesh peak.

In addition, it is not uncommon to see an increase in the 1xGM and 3xGM peaks.

Eccentricity can result in backlash, therefore you may also witness a peak at the natural frequency of the gear. This peaks (whose frequency is unknown) will also have 1X sidebands.

Gear mesh = Number of teeth x Shaft speed

Output speed = Input speed x Input teeth/Output teeth

Spectrum: The sideband frequency will correspond to the RPM of the eccentric gear, or the gear whose shaft is bent.

Time waveform: Thanks to the increase in turning speed modulation, the waveform should show a rise and fall in amplitude at a rate equal to the turning speed of the offending shaft.

Wear particle analysis: Unless wear occurs, oil analysis and wear particle analysis will not reveal this condition.

GMF 两侧只会有占主导成分的边带，而非是边带簇。

此外，1XGMF 和 3XGMF 幅值增长很常见。

偏心会导致游隙变化，这样会激起齿轮固有频率，齿轮固有频率（未知）会有 1X 边带。

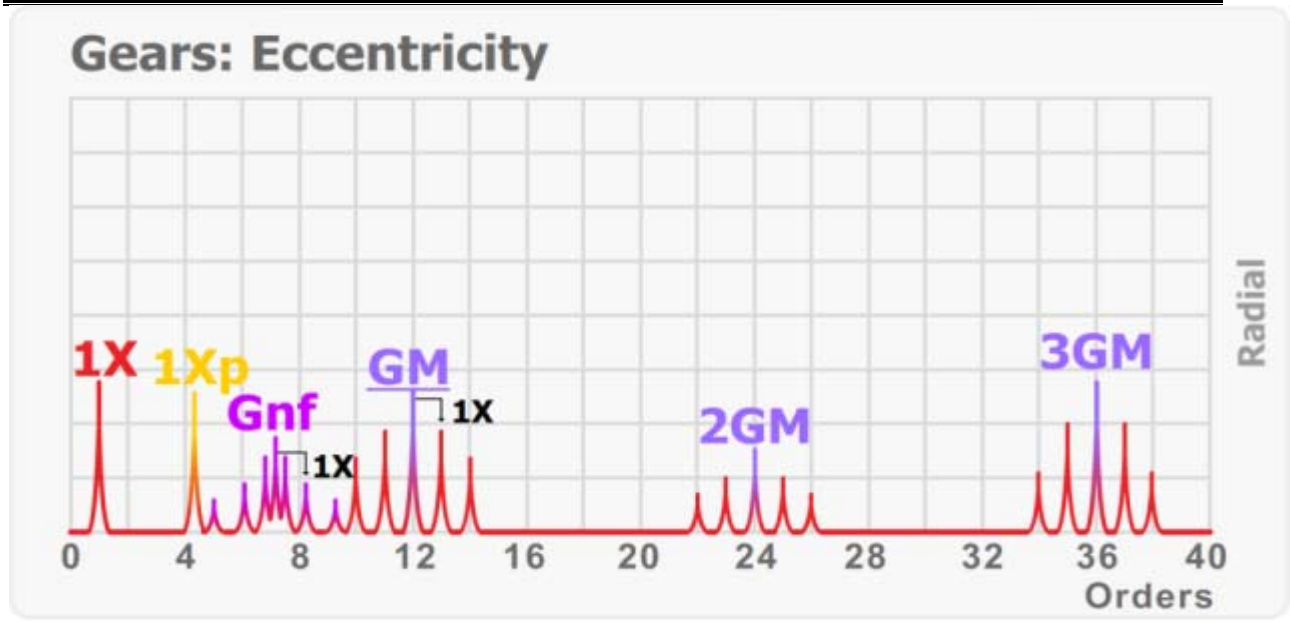
GMF=齿数 X 轴转速

输出转速=输入转速 X 输入齿轮齿数/输出齿轮齿数

频谱：边带频率对应着偏心的齿轮或弯曲的转轴。

时域波形：由于转速调制，可以看到波形幅值以故障齿轮转速周期上下波动。

磨粒分析：除非发生磨损，油液分析和磨粒分析不能发现此故障。



16.4 Gearbox: Misaligned gears 齿轮：齿轮不对中

Symptoms: 1X sideband around the gearmesh frequency harmonics 特征：GMF 谐频有 1X 边带

Misalignment often causes a high 2X turning speed vibration. When gears are misaligned you will see the gear mesh peak

不对中经常会导致 2X 幅值振动大。当齿轮不对中时，会看到 1XGFM 幅值增

increase in amplitude, but the 2X gear mesh peaks will increase far more.

While 1X turning speed sidebands will be present, 2X sidebands will be stronger.

The 3xGM peak and its sidebands will also increase in amplitude, therefore it is important to set your Fmax above this frequency.

Gear mesh = Number of teeth x Shaft speed

Output speed = Input speed x Input teeth/Output teeth

Spectrum: The 2X gear mesh peaks should be elevated, and the 2X turning speed sidebands should be higher in amplitude than the 1X sidebands.

Time waveform: The time waveform will have 2X turning speed modulation, and potentially the 2X gear mesh will be strong in the waveform.

Wear particle analysis: An uneven wear pattern is likely to develop on the teeth due to the angular contact; therefore you will be able to detect the wear particles.

长，但是 2XGMF 增长会更大。

1X 边带会出现，2X 边带幅值会更大。

3XGFM 和边带的幅值会增长，所以分析频率 Fmax 大于此频率很重要。

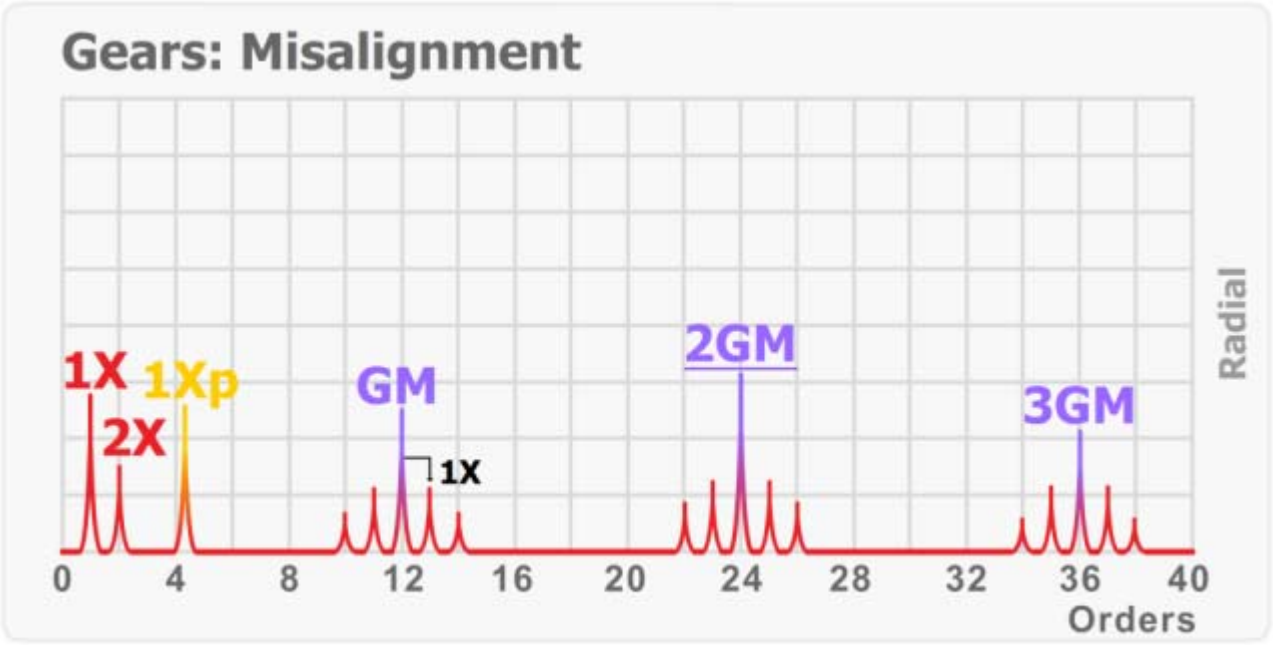
GMF=齿数 X 轴转速

输出转速=输入转速 X 输入齿轮齿数/输出齿轮齿数

频谱：2XGMF 的幅值应该是升高的，2X 边带的幅值会比 1X 边带更大。

时域波形：2X 转频调制，2XGMF 较强

磨粒分析：由于接触角度，会导致齿轮不均匀磨损，因此能检测到磨损的颗粒。



16.5 Gearbox: Gear backlash 齿轮：齿轮游隙

Symptoms: 1X sidebands around the gear mesh frequency 特征：GMF 有 1X 边带

Backlash often results when the gear is eccentric, therefore we will see an increase in amplitude of the 1X sidebands around the

齿轮偏心常常会导致游隙变化，就会看到 GFM 的 1X 边带幅值增大，此边带对

gearing mesh peak. The sidebands will correspond to the speed of the gear that is eccentric.

The impacting that results will excite the natural frequency of the gear. We do not know this frequency, but when a peak rises, with a broad base, with 1X sidebands, it is likely to be the natural frequency of the gear.

Gear mesh = Number of teeth x Shaft speed

Output speed = Input speed x Input teeth/Output teeth

Spectrum: The sideband frequency will correspond to the RPM of the eccentric gear, or the gear whose shaft is bent.

Time waveform: Thanks to the increase in turning speed modulation, the waveform should show a rise and fall in amplitude at a rate equal to the turning speed of the offending shaft.

Wear particle analysis: Unless wear occurs, oil analysis and wear particle analysis will not reveal this condition.

应偏心的齿轮。

冲击会激起齿轮固有频率。我们不知道这个频率是多少，但是当有个频率有 1X 边带，且有底部噪声时，这个频率很有可能是齿轮的固有频率。

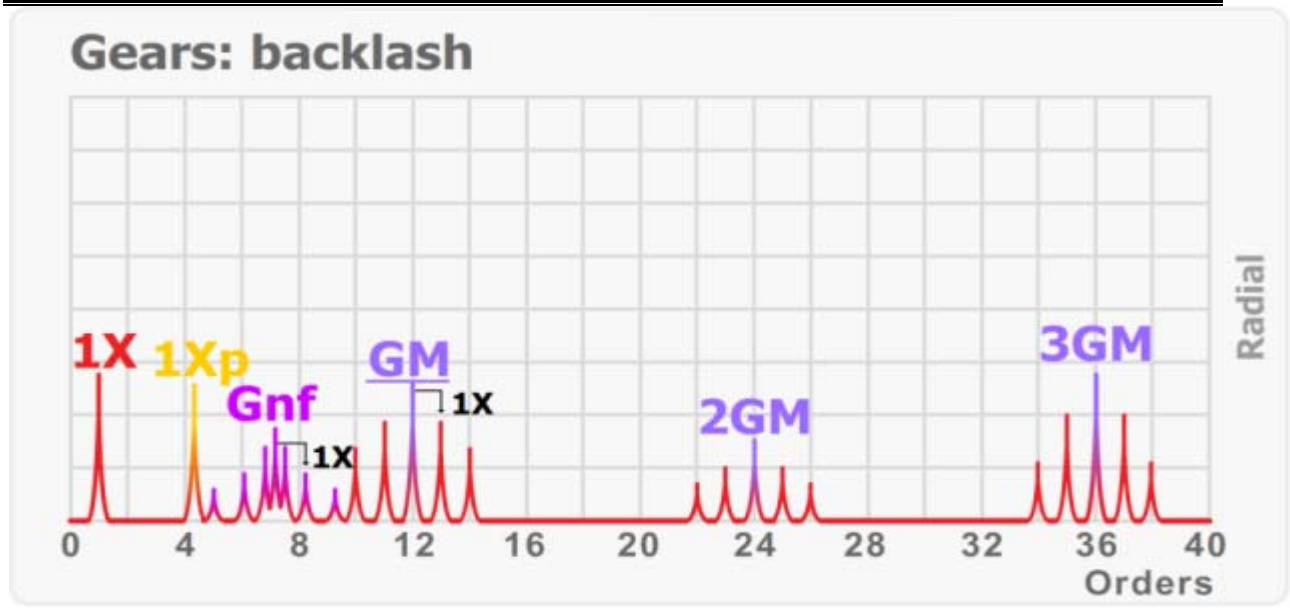
GMF=齿数 X 轴转速

输出转速=输入转速 X 输入齿轮齿数/输出齿轮齿数

频谱：边带对应的偏心的齿轮或弯曲的转轴。

时域波形：由于转速调制，可以看到波形幅值以故障齿轮转速周期上下波动。

磨粒分析：除非磨损发生，油液分析和磨粒分析不能发现此故障。



16.6 Gearbox: Cracked or broken tooth 齿轮：断齿

High 1X radial / Gear natural frequency / 1X sidebands around the gearmesh frequency 特征：1X 径向/Gnf/GMF 的 1X 边带

A cracked or broken tooth will generate a high amplitude peak at the turning speed of that gear, and it will cause the gear natural frequency to be excited. There will be 1X

有裂纹或断的齿轮将会产生 1X 和齿轮

sidebands around the gear natural frequency (1X of the gear with the damaged tooth).

There is no way to know ahead of time what the gear natural frequency is. You must watch for a new peak in the spectrum that has a broad base and sidebands as described.

Spectrum: Look for the gear natural frequency peak with sidebands. Spectrum analysis is not the best diagnostic tool.

Time waveform: If you view a time waveform that contains approximately 6-10 revolutions of the gear in question then the vibration change as the tooth comes into mesh should be clear to see. Circle plots and time synchronous averaging are also very useful analysis tools.

Wear particle analysis: Metal from the gear should be detected in wear particle analysis tests (and hopefully oil analysis tests as well).

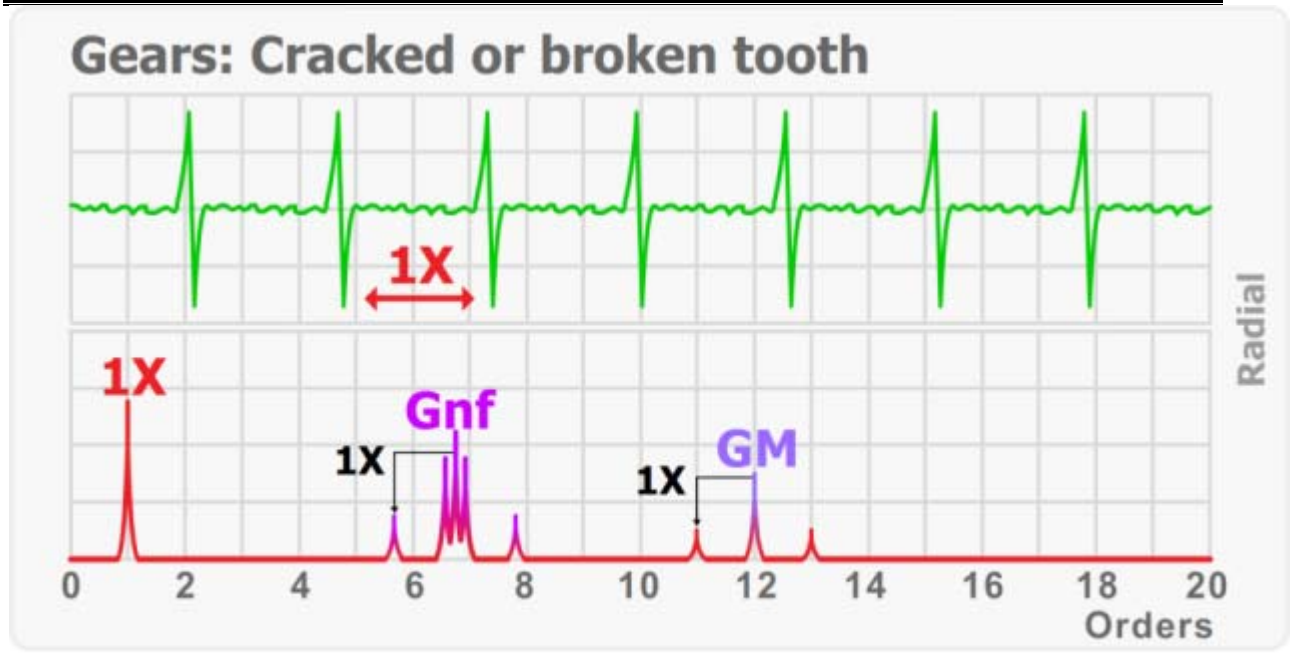
固有频率（Gnf），且 Gnf 有 1X 边带（故障齿轮）。

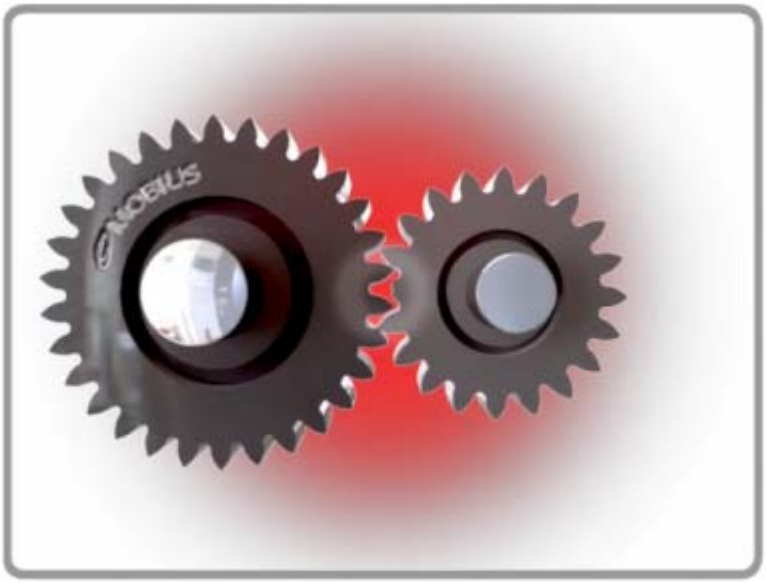
没有办法提前知道 Gnf 是多少。你必须留意频谱中新出现的有底部噪声的频率及其边带。

频谱：找到 Gnf 及其边带，频谱不是最好的分析工具。

时域波形：查看 6-10 周的长的时域波形，就能清楚的看到故障的齿在啮合过程中的幅值变化情况，故障齿轮每转一圈就会产生一次冲击。时域同步平均是很有效的分析工具。

磨粒分析：　应该能检测到齿轮上的金属。





16.7 Gearbox: Hunting tooth frequency 齿轮：追逐齿频率

Symptoms: Hunting tooth frequency and 2xHT 特征：追逐齿频率 HT 和 2xHT

The so-called "hunting tooth frequency" is the rate at which a tooth in one gear mates with a particular tooth in the other gear. If

追逐齿就是一个齿轮的齿牙与另一个齿轮的特定齿牙啮合的概率。如果齿数比是整数，如 1、

the gear ratio is an integer such a 1, 2 or 3, the hunting tooth frequency will be the RPM of the larger gear, and the same teeth will be in contact once per revolution. This will cause uneven wear on the gears - a small defect in one tooth will repeatedly contact the same teeth in the other gear causing localized wear on those teeth.

In practice, the hunting tooth frequency is used to detect faults on both the gear and pinion that may have occurred during manufacturing or as a result of mishandling. It is typically a low frequency, and you can hear a "growling" sound from the gearbox.

Spectrum: You may see a low frequency peak in the spectrum that confirms the low frequency growl you may hear.

Time waveform: Being a low frequency the time base of the time waveform will have to be long enough in order to see the change in vibration each time the two teeth come into mesh. Depending upon the number of teeth on each gear, then you may need to view 30 shaft rotations in order to see a few mesh events.

Wear particle analysis: Unless metal is lost you will not detect this fault with oil analysis or wear particle analysis.

HFD: Impacting will generate stress waves and excite natural frequencies in the bands used by demod/enveloping/PeakVue, etc. Therefore you should expect to see harmonics of 1X turning speed in your demod/envelope/PeakVue etc. spectrum.

2、3，追逐齿频率会是大齿轮的 RPM，每转一周会啮合相同的齿数。这会导致齿轮不均匀磨损。一个齿上的小缺项会与另一个齿轮的同一个齿重复啮合，造成这些齿局部磨损。

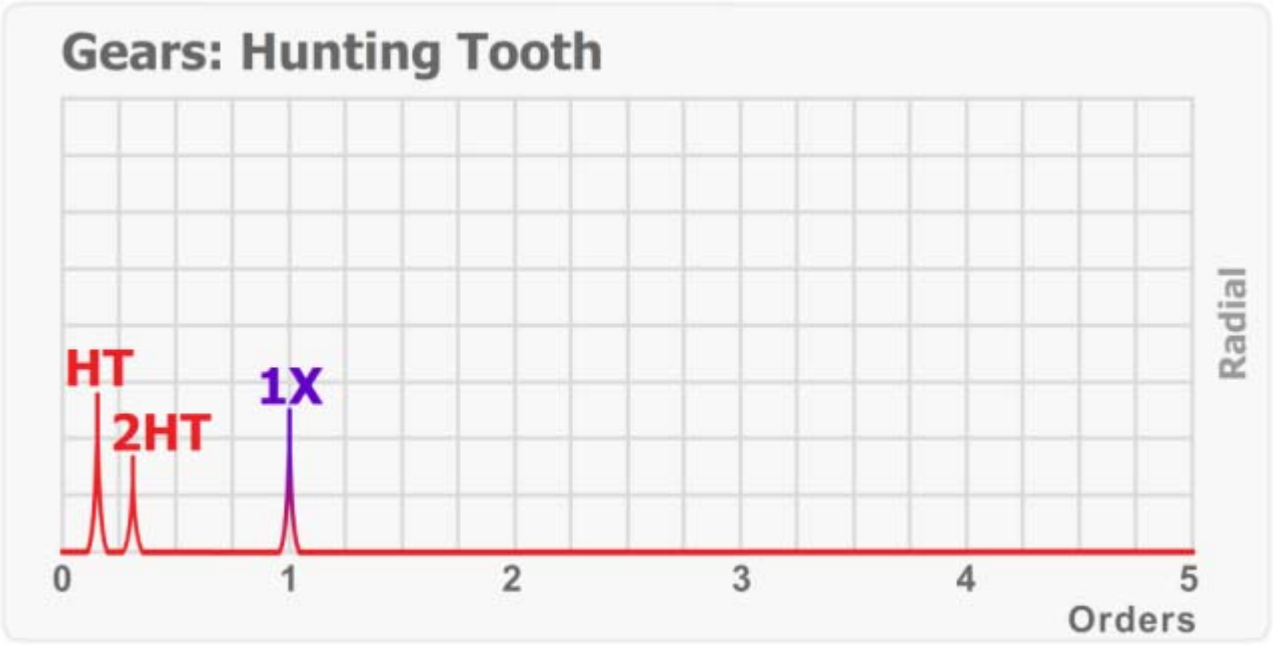
实际上，追逐齿频率常用来发现大小齿轮在生产过程和误操作中发生的故障。通常是低频，你会听见齿轮箱在“咆哮”

频谱：频谱中会有低频，这些低频咆哮就是你听到的。

时域波形：由于是低频，波形时间长度（越 30 周）需要足够长，才能看到齿轮啮合时故障的振动。

磨粒分析：除非有金属，油液分析和磨粒分析不能发现此故障。

HFD:冲击会产生压力波并激起某频段的固有频率。在解调/包络/ PeakVue 谱上会看到 1X 转频及谐频。



17 Couplings 联轴器

17.1 Couplings: Coupling unbalance 联轴器：联轴器不平衡

Symptoms: High 1X radial 特征：1X 幅值高径向

The coupling may be out-of-balance for a number of reasons: lost part, incorrect assembly, key fitted incorrectly, excessive lubrication in a gearflex coupling and more. Like all unbalance forces you will witness a strong source of vibration in the radial direction at the turning speed of the shaft.

联轴器不平衡有以下原因：少部件、不正确安装、齿式联轴器润滑过多等。像所有的不平衡力，你会看到径向 1X 转频幅值高。

Spectrum: Look for a high 1X peak in the spectrum. It should be seen on spectra taken in the vertical and horizontal direction on the components on either side of the coupling.

频谱：查看联轴器两侧垂直和水平方向上的 1X 峰值。

Waveform: There should be a strong sinusoidal shape to the waveform (especially when viewed in velocity or displacement).

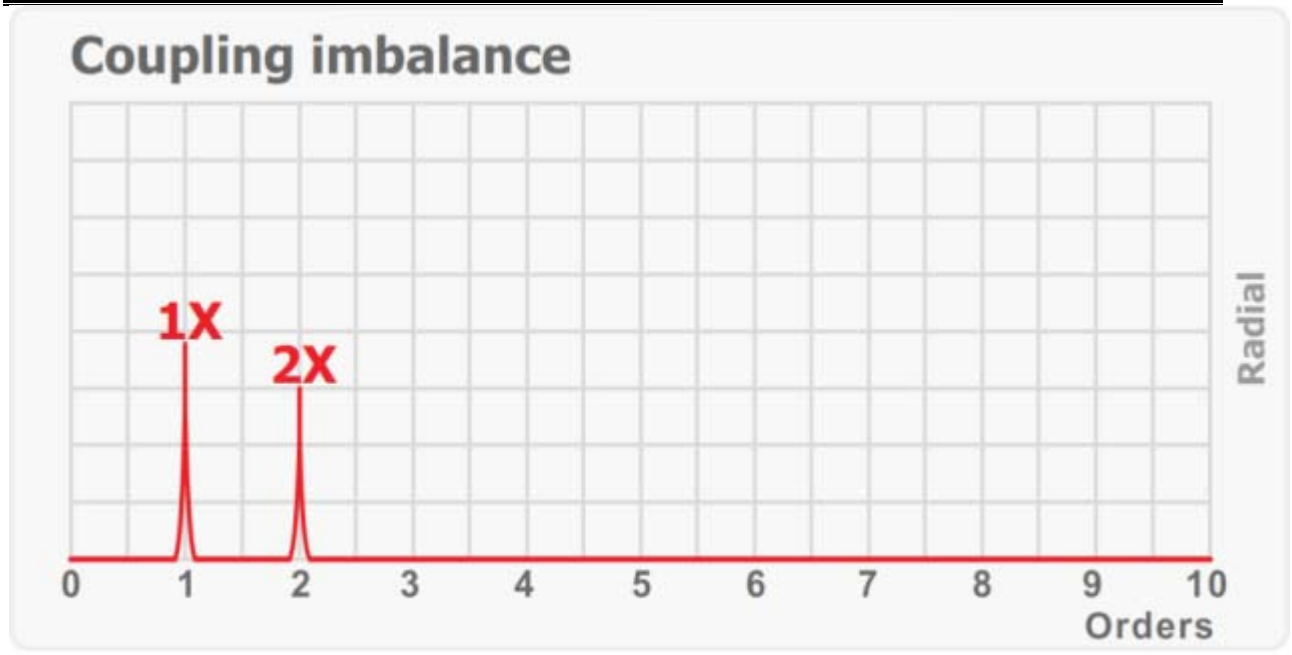
时域波形：速度或位移单位，应是正旋波。

Phase: There should be a 90° phase difference between the vertical and horizontal readings.

相位：垂直和水平应该是 90°差。

Strobe: You should freeze the coupling to see if the source of unbalance is visible.

频闪仪：与联轴器同频，查看是否不平衡。



17.2 Couplings: Non-parallel coupling faces 联轴器：非平行面

Symptoms: High 1X (small 2X) axial 特征：轴向 1X 幅值高（2X 幅值小）

If the coupling is not true, i.e., has non-parallel flange faces, a vibration pattern similar to misalignment is produced. There

如果联轴器的两侧法兰非平行，那么会

will be a strong 1X axial vibration with an additional 2X component.

This is different to shaft misalignment, although it may be difficult to distinguish between them with vibration readings.

Spectrum and phase readings will be useful.

Spectrum: Look for the high 1X peak in the axial direction.

Waveform: A strong source of vibration at the turning speed will cause the waveform to look sinusoidal. If the units are velocity and your time base is set so that you can see more than 3 rotations and less than 20 shaft rotations then this pattern should be obvious. Of course, you will need to acquire the waveform in the axial direction.

Phase: There will be a 180° phase shift across the coupling in the axial direction. Ensure that you adjust for sensor orientation.

产生类似不对中的振动。轴向会有很大的 1X，还有 2X。

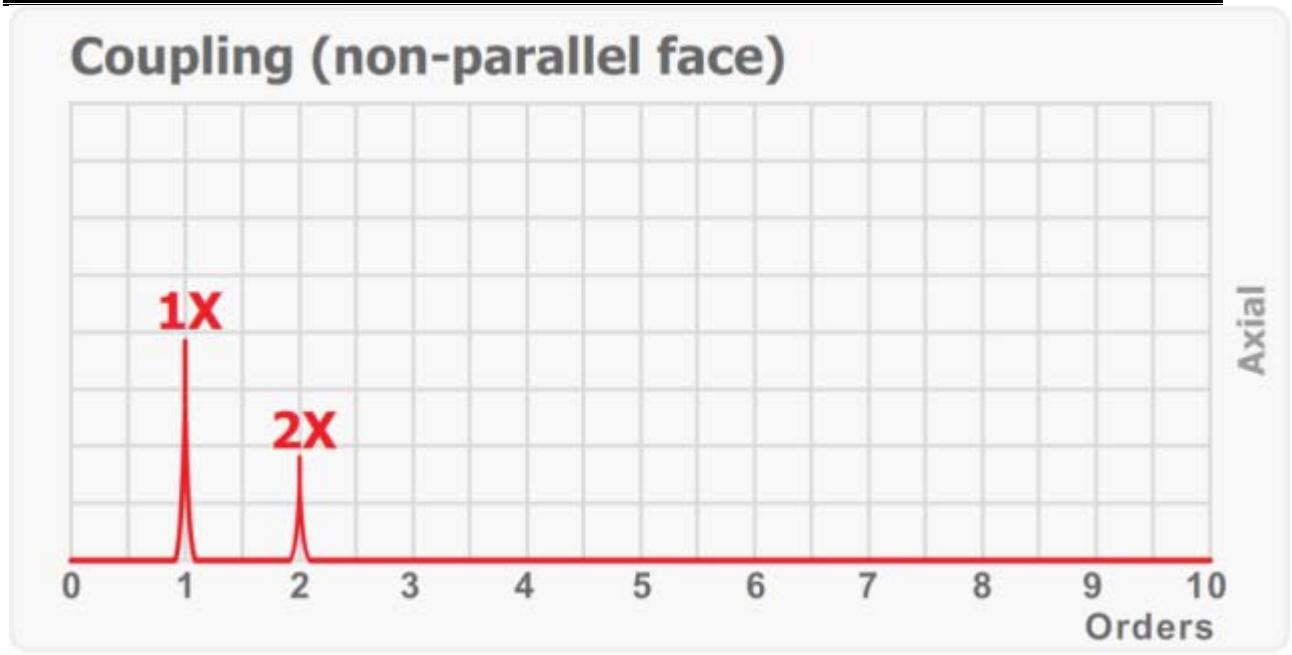
跟轴不对中故障不同，但是很难通过振值进行区分。

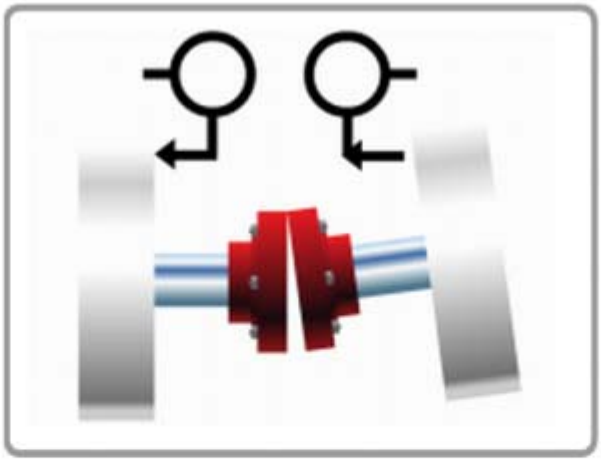
频谱和相位会有用。

频谱：查看轴向 1X 幅值。

时域波形：采集轴向时域波形，时间长度 3-20 周，采用速度单位，会看到 1X 转频的正旋波。

相位：联轴器两侧轴向相位差 180°，注意传感器方向一致。





17.3 Couplings: Coupling wear 联轴器：联轴器磨损

Symptoms: Harmonics of 1X 特征：1X 谐频

A worn coupling can present with the same symptoms as looseness: a strong series of turning speed harmonics.

联轴器磨损跟松动的特征一致，丰富的 1X 谐频。

Note that the vibration associated with looseness would normally be seen on the component that is suffering from looseness. In the case of coupling wear, the vibration should be detectable on both components that are coupled together.

注意，松动方式的振动通常只能在松动的部件上看到。而联轴器磨损，振动会在联轴器连接两侧部件上都发现。

Note that 3-jaw couplings will show 3X vibration – see the separate section.

注意，3 爪联轴器会产生 3X 振动，请参考相关章节。

Spectrum: Coupling wear will generate a large number of harmonics and may cause the noise floor to rise.

频谱：联轴器磨损会产生 1X 谐频并可能导致底部噪声抬起。

Phase: Coupling wear generates "random" vibration, so the phase is erratic. It is important to view the phase reading "live" so you can see if the phase reading (relative to the tachometer or relative to another point on the machine) is steady.

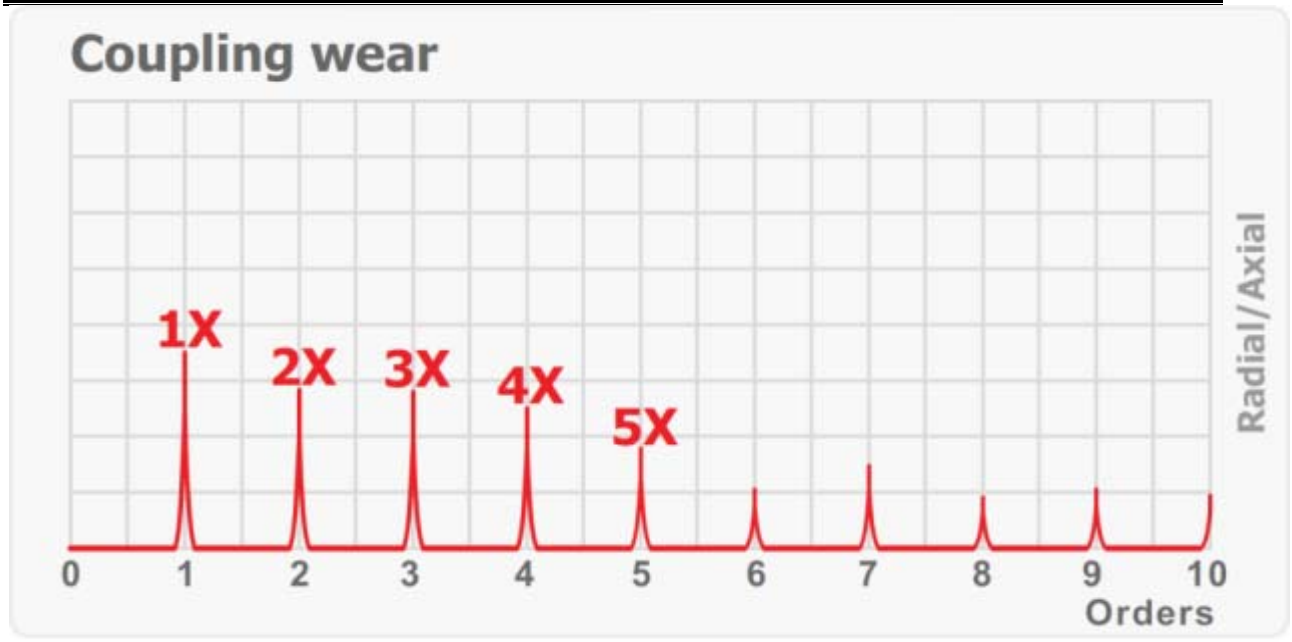
相位：联轴器磨损会产生“随机”振动，所以相位是不稳定的。实时相位读数是否稳定很重要的（转速传感器相对于键槽）。

Waveform: Impacting is quite obvious in the time waveform. It is best to use units of acceleration (g's or mm/sec^2).

时域波形：时域波形中冲击很明显，最好使用加速度单位。（g's 或 mm/sec^2）

HFD: Impacting will generate stress waves and excite natural frequencies in the bands used by demod/enveloping/PeakVue, etc. Therefore you should expect to see harmonics of 1X turning speed in your demod/envelope/PeakVue etc. spectrum.

HFD: 冲击会产生某频段内的压力波和激发共振频率，可以使用解调/包络/PeakVue 等。所以会在解调谱中看到 1X 谐频。



17.4 Couplings: Misaligned 3-jaw coupling 联轴器：3 爪联轴器不对中

Symptoms: High 3X radial 特征：3X 径向幅值高

A 3-jaw coupling will exhibit high 3X vibration if it is misaligned. It is common for peaks at 6X and 9X to also be visible.

3 爪联轴器如果不对中，会产生 3X 峰值。6X、9X 峰值出现很正常。

Note that a 4-jaw coupling will exhibit vibration at 4X (and commonly 8X and 12X).

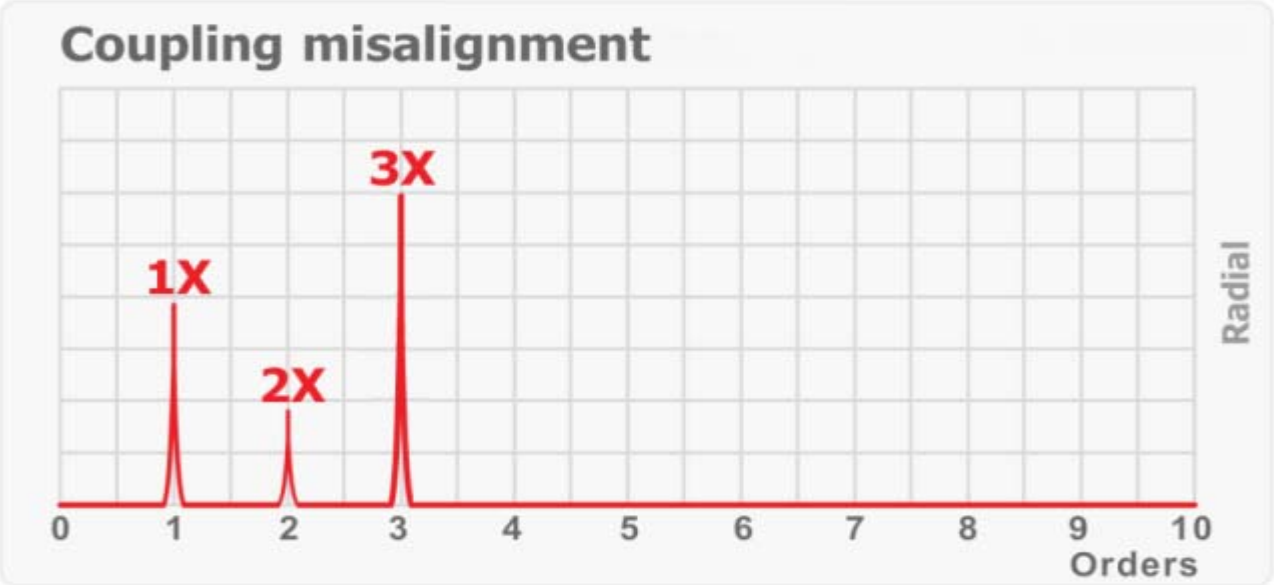
Spectrum: Look for the 3X, 6X and 9X peaks.

Waveform: If the spectrum is dominated by 3X vibration then this pattern will also be visible in the waveform. The waveform will not add a great deal to the diagnosis. If 6X and 9X vibration is also present then the waveform will be even more complicated.

注意：4 爪联轴器会产生 4X（和 8X、12X）

频谱：查看 3X、6X、9X。

时域波形：频谱中 3X 占主导，波形中也是。波形帮助不大，如果有 6X、9X，那么波形会比较复杂。



17.5 Couplings: Locked gearflex coupling 联轴器：齿式联轴器卡住

Symptoms: High 3X radial 特征：3X 径向幅值高

A gearflex coupling must be properly lubricated so that the teeth are able to make sliding contact. It is essential that the correct lubricant is used. If the coupling locks, there is no sliding contact and the machine behaves as if it has a solid shaft, twisting it in an "s" shape. This generates high axial vibration and has been known to generate a high 3X vibration.

It is also common to find that the vibration changes suddenly from the "unlocked" (correct) to the "locked" state. Stopping and restarting the machine may unlock the coupling, enabling it to perform correctly. But it may lock again, increasing vibration levels, and increasing loads on the coupled components (and bearings, shaft and coupling).

Spectrum: Look for high axial vibration and the presence of the 3X peak.

Phase readings: Phase readings will provide an indication that the coupling is locked as it will behave like a solid shaft.

Additional test: Stop the machine and start it again (if possible).

Strobe: Viewing the coupling with a strobe may give you a clue to what is happening.

齿式联轴器必须正确润滑，这样齿才能滑动接触。正确的润滑剂很重要。如果联轴器卡住，就不会有滑动接触，设备就像是刚性轴，扭曲成“S”型。这会产生很大的轴向振动还有很大的 3X 峰值。

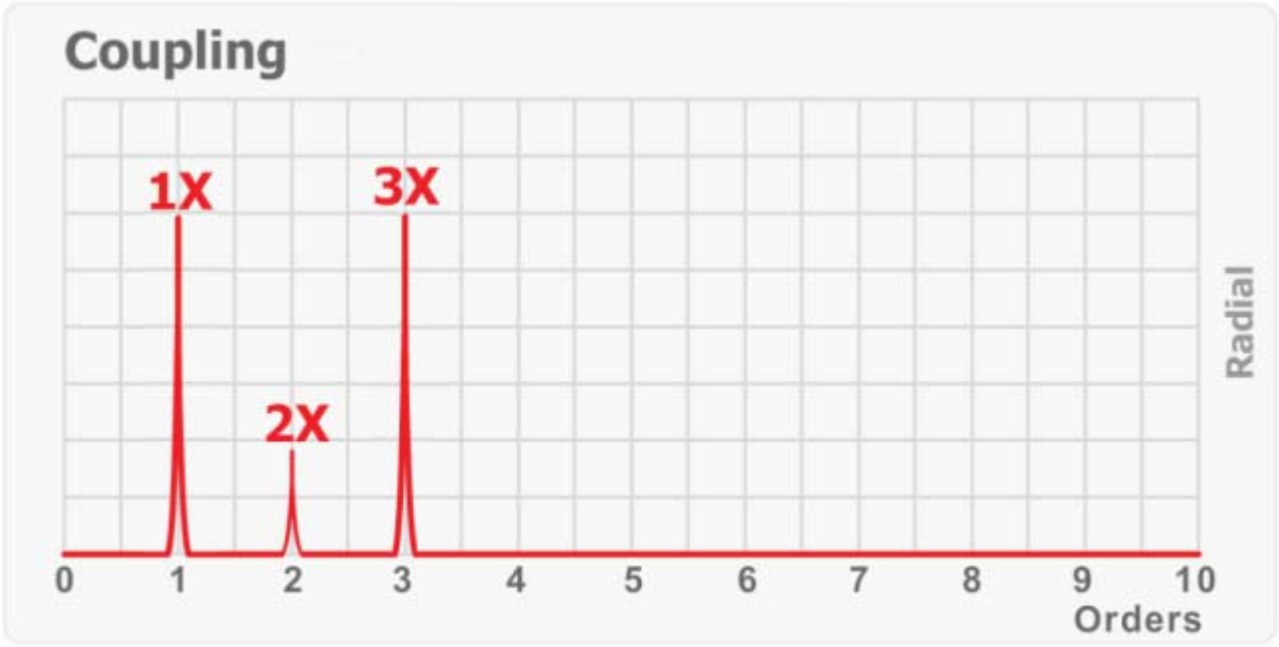
联轴器从“解锁”状态切换到“卡住”状态，振动会突然变化，这很常见。启停设备会“解锁”联轴器，使它正常工作。但它可能再次卡住，振值会变大，联轴器负载会变大（轴承、转轴、联轴器）

频谱：查看轴向振动会 3X 峰值。

相位：当联轴器卡住，表现的像刚性轴，相位会提供很好的指示。

其它测试：停机然后开机（如果可能）

频闪仪：使用频闪仪观察联轴器，可能发现蛛丝马迹。



18 Belt drives 带传动

18.1 Belt drives: Worn belts 带传动：皮带磨损

Symptoms: Belt rate with harmonics 特征：皮带通过频率谐频

If a belt is worn or loose you will witness a peak at the belt rate, and harmonics. The highest amplitude peak in the series will often be the twice the belt rate frequency.

The key forcing frequency is known as the "belt rate" or "fundamental belt pass frequency". It is the rate at which a point on the belt passes a fixed reference point. It is always less that the speed of either sheave.

It is calculated as follows:

Driven RPM =Driving RPM x Driving sheave diameter/Driven sheave diameter

Belt freq = PI x Sheave RPM x Sheave diameter/Belt length

Where PI = 3.1416

Spectrum: Look for the belt rate peak (sub-synchronous) and harmonics. Sometimes the belt rate peak may be cut off by the high pass filter, but the harmonics will be present.

Time waveform: If the belts are simply worn then the time waveform will not be the best analysis tool. If a belt has a distinct point of damage then there will be an event in the waveform once per belt revolution.

Strobe: A strobe is a very useful tool. If you use the strobe to freeze the movement of the belts then you can inspect them without stopping the machine. You can also detect slip on multi-belt systems.

如果皮带松动或磨损，你会看到皮带通过频率及谐频。2X 皮带通过频率的幅值会最高。

关键频率是“皮带通过频率”，它是指皮带上一个点通过固定参考点的速度。总是小于任一槽轮的转速。

计算公式：

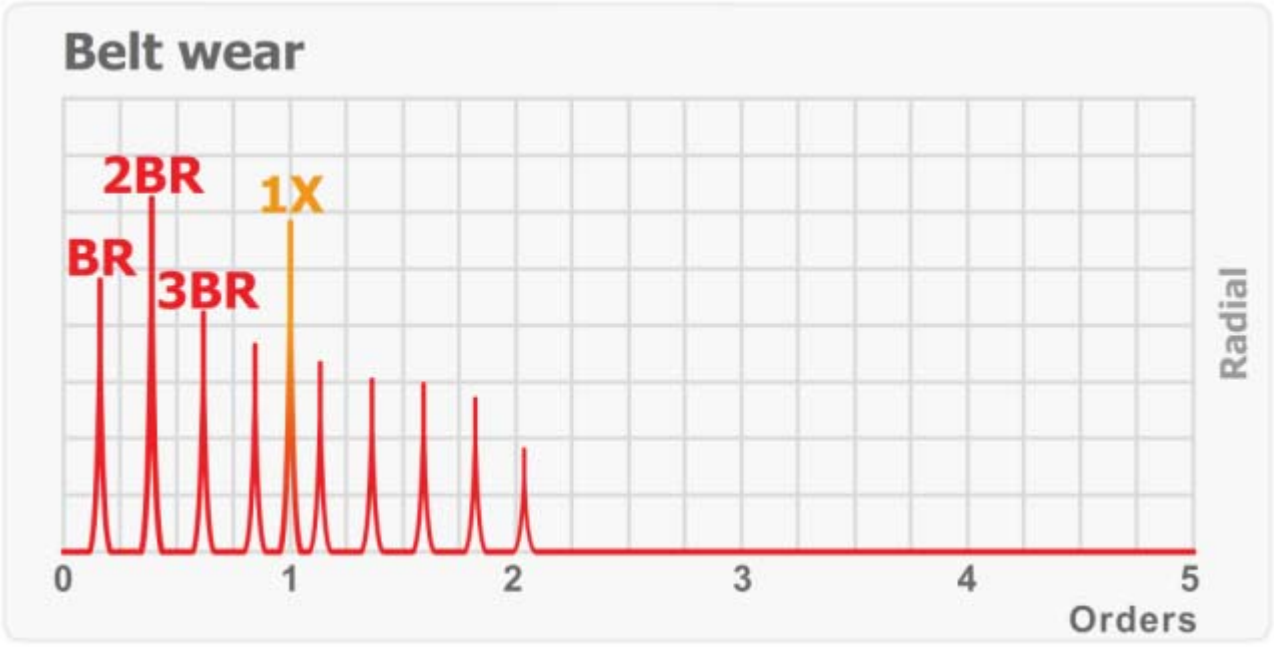
皮带通过频率=PI x 槽轮 RPM x 槽轮直径/带长

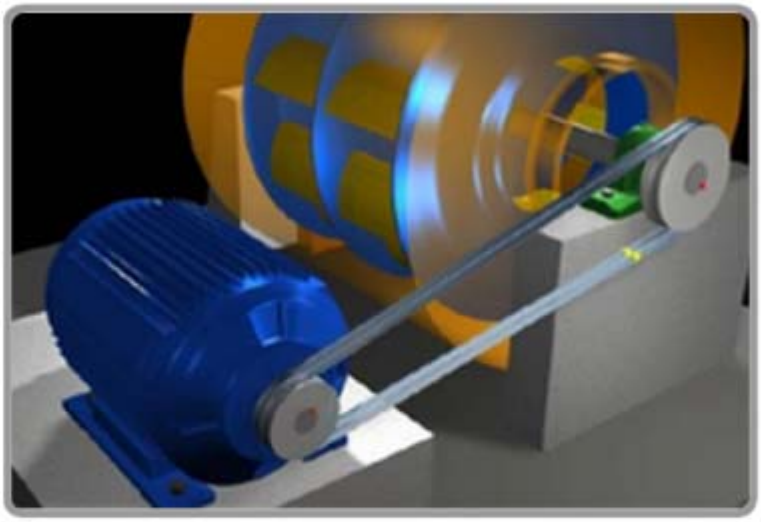
PI=3.1416

频谱：查看皮带通过频率（亚同步）及谐频。有时皮带通过频率被高通滤掉，但是谐频还在。

时域波形：如果皮带只是磨损，时域波形没啥表现。如果皮带有个点有明显损伤，皮带每转一周，都会有冲击。

频闪仪：频闪仪是很有用的工具。不用停机，就能查看皮带状态，也能查看多皮带出现打滑的情况。





18.2 Belt drives: Sheave misalignment 带传动：槽轮不对中

Symptoms: High 1X axial 特征 ： 1X 轴向幅值高

Misalignment of sheaves produces high vibration at 1X turning speed of each component (e.g. fan and motor),

槽轮不对中会产生各部件（如电机和封建）的轴向 1X 峰值。

predominantly in the axial direction. On occasion you will also see harmonics of belt rate (belt frequency) in the axial direction.

Misalignment can take one or more of three forms – see the graphic.

Spectrum: Look for the high 1X peak in the axial direction.

Time waveform: The velocity time waveform should look quite sinusoidal unless there are other sources of vibration from the machine.

Phase: Phase readings taken in the axial direction on both components (motor and fan, for example) will be approximately 180° out of phase.

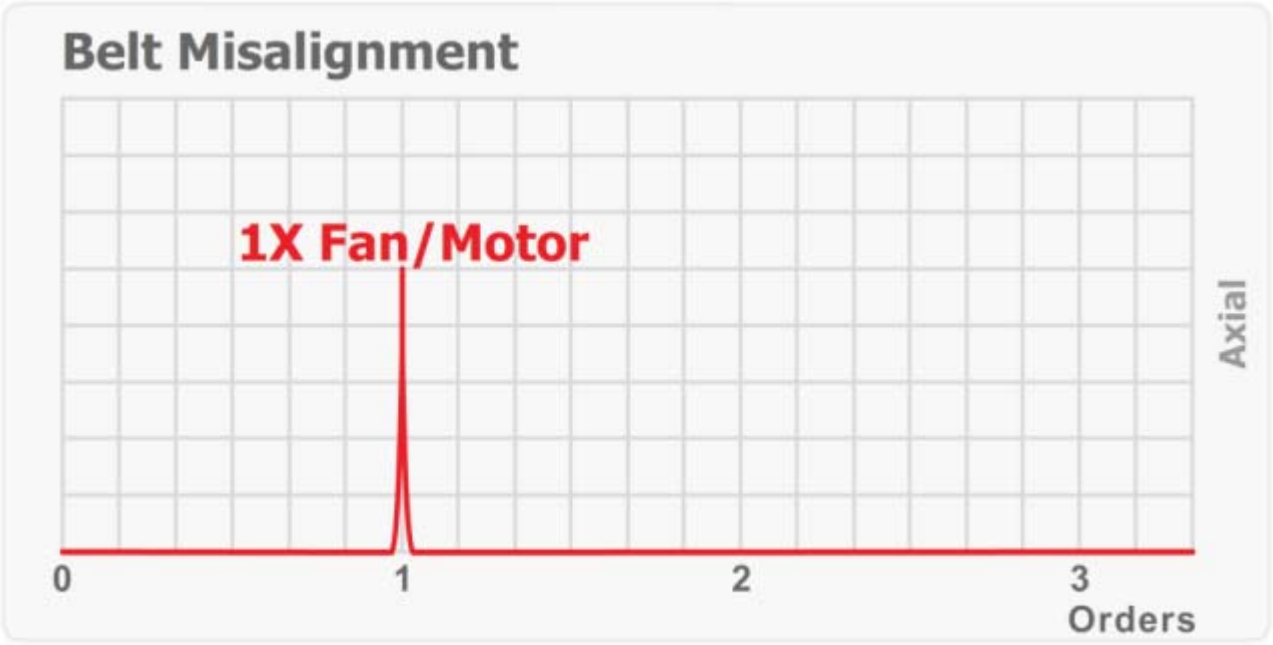
有时轴向也能看到皮带通过频率谐频。

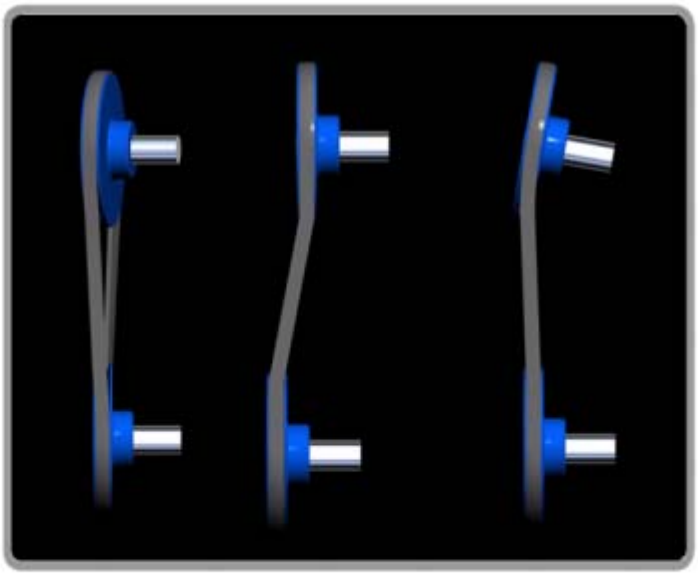
不对中有三种形式，查看下图。

频谱：查看轴向 1X 峰值。

时域波形：除非有其它振动源，速度单位的时域波形是正旋波。

相位：两个部件（电机和风机）的轴向相位差约 180°。





18.3 Belt drives: Belt resonance 带传动：皮带共振

Symptoms: High 1X radial 特征：1X 径向幅值高

Resonance in the belt can cause high amplitudes if the belt's natural frequency should happen to coincide with either the

如果皮带固有频率正好和驱动和被驱动槽轮的 RPM 重合，那么皮带共振会产

driving or driven sheave RPM. The natural frequency can be altered by either changing the length or tension of the belt.

生很高的幅值。改变皮带的长度和张力会改变皮带的固有频率。

Spectrum: If the belt's natural frequency coincides with the RPM of either driven component then you expect that the 1X peak to increase in amplitude. The base of the peak may be more broad than normal.

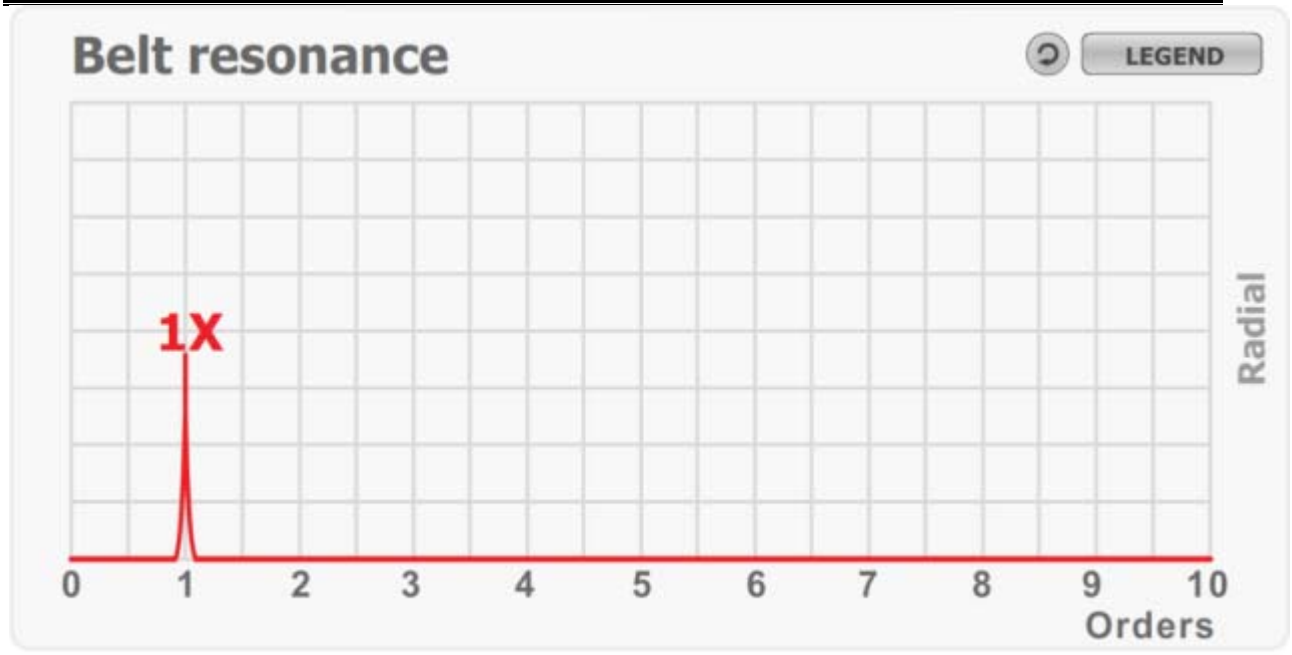
频谱：如果皮带固有频谱和任一槽轮 RPM 相同，那么会看到 1X 幅值变大，底部噪声也会抬起。

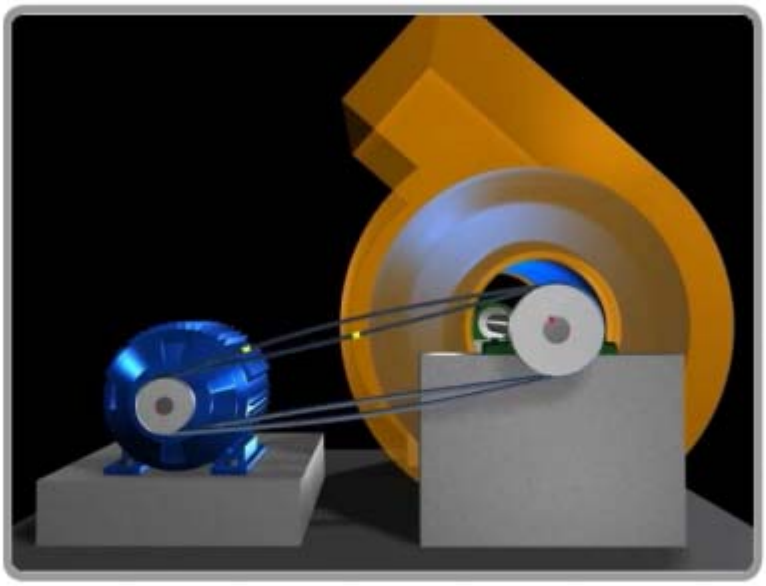
Run-up test: If you can monitor the vibration as the machine comes up to speed you will expect to see the 1X amplitude increase quickly as it reaches its nominal RPM.

启机测试：监测设备转速上升的振动，接近正常转速时，1X 幅值会快速变大。

Strobe: If you synchronize the strobe with the RPM of the driven or driving sheave/pulley RPM then you may be able to see the belts "flapping".

频闪仪：频闪仪与驱动或被驱动槽轮同步，会看到皮带“拍打”。





19 Things you should know

19.1 Things you should know: Warning 警告

There is a lot to learn about vibration analysis and diagnosing machine faults. This product does not provide the entire story. It is designed to provide you with a reminder of what you hopefully already know; it is not designed to provide you with definitive information that you could use to diagnose a fault.

对设备进行振动分析故障还需要知道很信息。本文中信息不全。仅供参考。

In addition, there are a large number of different details (type of coupling, type of machine, the speed of the machine, and much more) that can mean that the spectrum could like quite different to the spectra shown in this product.

另外，还有很多不同的信息（联轴器类型、设备类型、设备转速等），这意味着频谱会有所不同。

Or to put it another way, and to keep the lawyers happy, don't base critical decisions on the information found in this product.

本文对诊断后果，概不负责。

19.2 Things you should know: Data Analysis 数据分析

In general we have commented on the use of spectra, time waveforms, phase, strobes, HFD, ultrasound and wear particle analysis.

总的来说，我们谈到了频谱、时域波形、相位、频闪仪、HFD、超声、磨粒分析

Spectra: We will often comment on patterns that may require measurements from specific axes (vertical, horizontal and axial), and we may comment on the need to measure up to a specific Fmax value to ensure that the frequencies of interest are measured. We may also comment on the resolution required, particularly in relation to sidebands – if you do not have the required resolution you may not be able to detect the presence of the sidebands.

频谱：我们通常需要测量垂直、水平、轴向的数据。需要设置合理的 Fmax 最大分析频率，以便捕捉到故障频率，也要设置合理的分辨率，已便看清楚边带。

Note that the peaks referred to as '1X', '2X' etc. relates to the turning speed of the shaft. '1X' is the turning speed. '2X' is twice the turning speed. Note that a machine may have multiple shafts that turn at different speeds.

注意，1X、2X 峰值，指的是 1 倍转频和 2 倍转频。注意多轴设备可能有不同转速。

Note also that the spectral plots are all displayed in velocity. (If they were in displacement or acceleration the relative amplitudes between high frequency and low frequency peaks would be quite different.)

还要注意频谱一般是速度单位（低频信号请使用位移单位，高频信号请使用加速度单位）

Waveforms: There are generally two keys to collecting waveforms correctly. First, if the waveform is in units of acceleration is it easier to detect bearing, looseness, and gearbox faults (faults that involve impacts

时域波形：采集时域波形两点很重要。第一、加速度时域波形对诊断轴承、松动、齿轮故障（冲击和磨损相关）很有

and wear). If the waveform is in units of velocity, faults such as unbalance, misalignment and other smoother, lower frequency faults will be easier to detect.

效。第二，速度时域波形诊断不平衡、不对中、等其它低频故障很有效

Phase: Phase is a very useful diagnostic tool – it can help you to determine the exact nature of a fault after spectra or waveform measurements give you a clue that a fault exists.

相位：相位很有用。在时域波形和频谱初步诊断后，确定故障的关键因素。

All phase angles cited (e.g. "in-phase", "90° out of phase", and "180° out of phase") are not exact values. In each case you can be up to 30° different and still feel that the rule is true.

所有引用的相位角度（如"in-phase", "90° out of phase", and "180° out of phase"）都不是精确的角度。误差±30°，规则仍然有效的。

Remember to correct the phase readings based on the orientation of the accelerometer.

相位比较时，注意加速度传感器的安装方向

HFD: We have used 'HFD' as the generic term for all of the high frequency detection tools such as demodulation, acceleration enveloping, PeakVue, Shock Pulse, Spike Energy, and SWAN. Yes, these methods all have their differences, but for this application we have added the 'HFD' information to denote whether these high frequency methods should provide additional diagnostic information.

HFD：我们使用"HFD"作为高频检测技术的统称，如包络、解调、PeakVue, Shock Pulse, Spike Energy, SWAN。虽然这些技术各自处理方式不同，但是不管哪种技术都应通过更多诊断信息。

Strobe: A stroboscope is an excellent tool for observing components that are normally rotating. By synching the strobe with the rotation speed (or other key frequency) it can be possible to make very important and revealing observations.

频闪仪：频闪仪是观察部件转动时情况的好工具。频闪仪与转速同步，就能看到很多有用信息。

Wear particle analysis: Primarily in the gearbox section, we have also added some comments related to the application of wear particle analysis and oil analysis. These are excellent tools, and in the case of gears and oil lubricated bearings, this technology can provide an early warning and clear diagnostic information.

磨粒分析：主要针对齿轮箱，对于油润滑的轴承和齿轮，可提供早期预警和明确的诊断信息。

19.3 Things you should know: Useful facts 有用信息

Here are a few terms and abbreviations we use:

我们使用的术语和缩写

TS: Turning Speed [The speed of the shaft in question]

TS：转频（故障转轴的速度）

1xTS: Shaft Turning Speed [The speed of the shaft in question]

2xTS: Twice the shaft Turning Speed [The speed of the shaft in question]

1X: One times the turning speed of the shaft

2X: Two times the turning speed of the shaft

LF: Line frequency [50 Hz or 60 Hz]

2xLF: Twice line frequency (100 Hz or 120 Hz)

GM: Gearmesh frequency [The number of teeth on the gear times the turning speed of the gear]

Gnf: Gear Natural Frequency [The natural frequency is unknown, but if there is impacting or wear in the gears the natural frequency will be excited and the peak (hump) will appear]

PV: Pump Vane rate [The number of vanes on the pump times the turning speed]

BP: Blade Pass rate [The number of blades on the fan times the turning speed]

BPFO: Ball Pass Frequency Outer-race [The rate at which a ball or roller will pass a point on the outer race]

BPFI: Ball Pass Frequency Inner-race [The rate at which a ball or roller will pass a point on the inner race]

BSF: Ball Spin Frequency [The rate at which a point on a ball or roller will contact the inner OR outer race]

FTF: Fundamental Train Frequency [The rate at which the bearing cage travels around the bearing. Also called the Cage Rate.]

Orders: Multiples of the turning speed of the shaft

PP: Pole Pass frequency [The slip frequency times the number of poles.]>

Slip: Slip frequency [The difference between the actual RPM and the synchronous speed.]

1xTS: 转轴速度（故障转轴的速度）

2xTS:2 倍转轴速度（故障转轴的速度）

1X：一倍转轴速度

2X:2 倍转轴速度

LF:线频（50 或 60Hz）

2xLF: 2 倍线频（100 或 120Hz）

GM:齿轮啮合频率（齿数 X 转速）

Gnf：齿轮固有频率（该频率不知，如果齿轮有磨损或冲击，该频率会被激起，驼峰会出现）

PV:流道通过频率（泵的流道数 X 转速）

BP:叶片通过频率（风机的叶片数 X 转速）

BPFO:轴承外滚道通过频率

BPFI:轴承内滚道通过频率

BSF:滚动体通过频率

FTF:保持架通过频率

Orders：阶次

PP:极通过频率

Slip：滑差频率

19.4 Things you should know: Spectral Ski-slope 滑雪坡

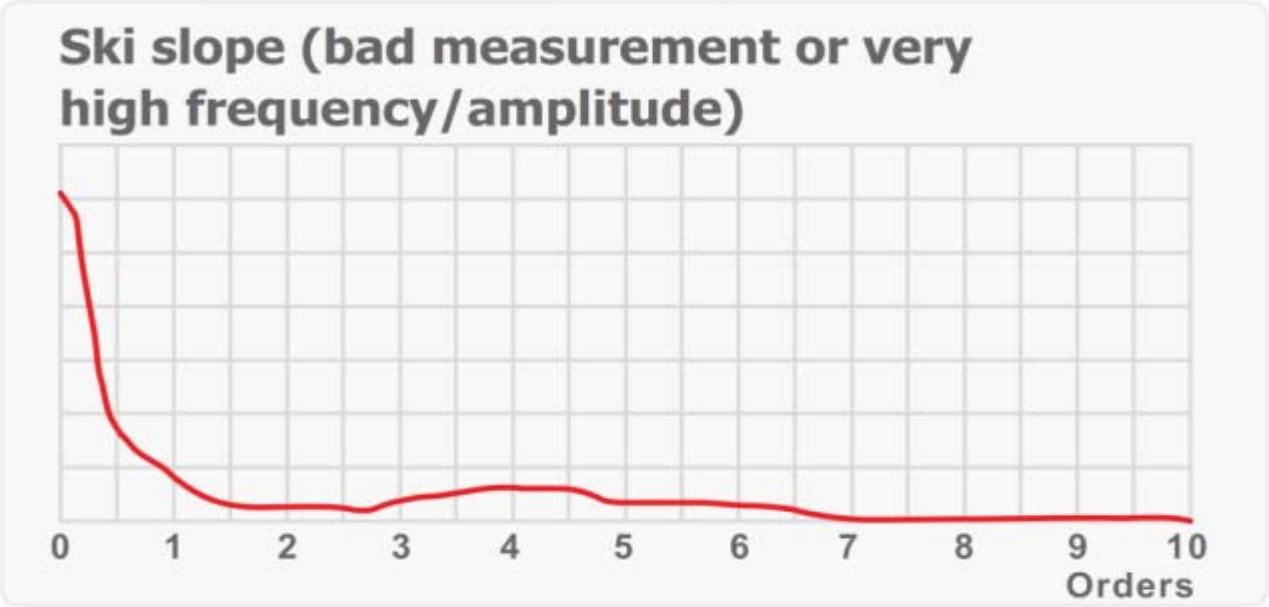
Symptoms: High near 0 Hz, decaying down across the spectrum 特征：接近 0Hz，幅值大幅衰减

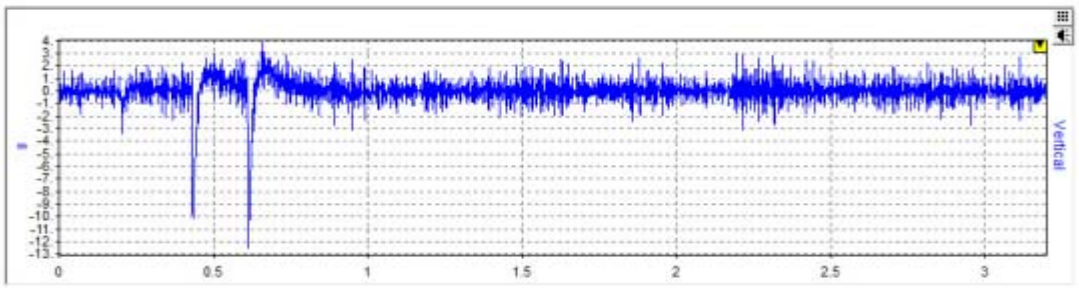
If you see the classic ski-slope curve, then there is either a fault with the sensor, or the sensor experienced a shock/transient during the measurement process. The transient may be mechanical (the sensor was bumped, or experienced very high vibration), thermal (the sensor was placed on a very hot or cold surface), or electrical.

The spectrum will have a ski-slope and a raised noise-floor at the high frequency end of the spectrum if the transducer becomes "saturated". This typically occurs when there is a source of high vibration at high frequency such as cavitation.

如果看到经典的滑雪坡曲线，可能传感器故障，或在测量时传感器遭遇冲击或瞬态信号。瞬态可能是机械式的（传感器被撞倒，或遭遇很高的振动），热量（传感器放置在很高的或很冷接触面上），或电磁作用。

如果传感器“过载”，频谱中会有滑雪坡且高频处底部噪声抬起。这种情况通常发生在高频振动源处，如气蚀。





19.5 Things you should know: Raised noise floor 底部噪声抬起

Symptoms: Bottom of spectrum raised 特征：底部噪声抬起

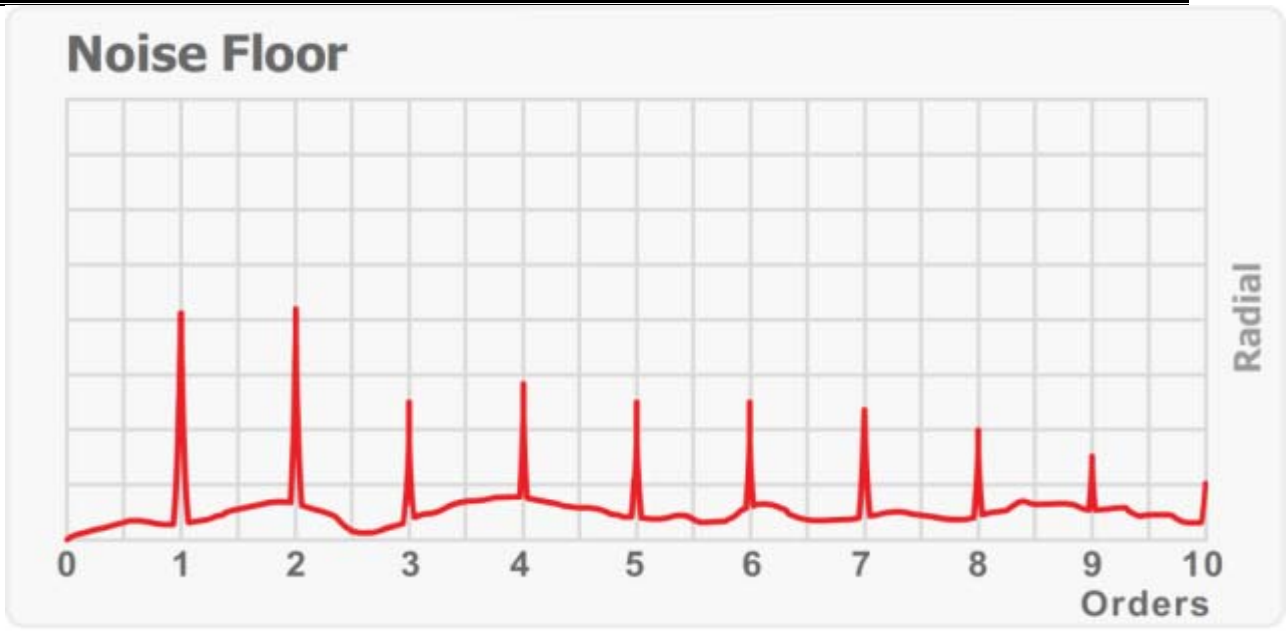
If the entire noise floor is raised, it is possible that you have extreme bearing wear. If the noise is biased toward the higher frequencies, then you may have

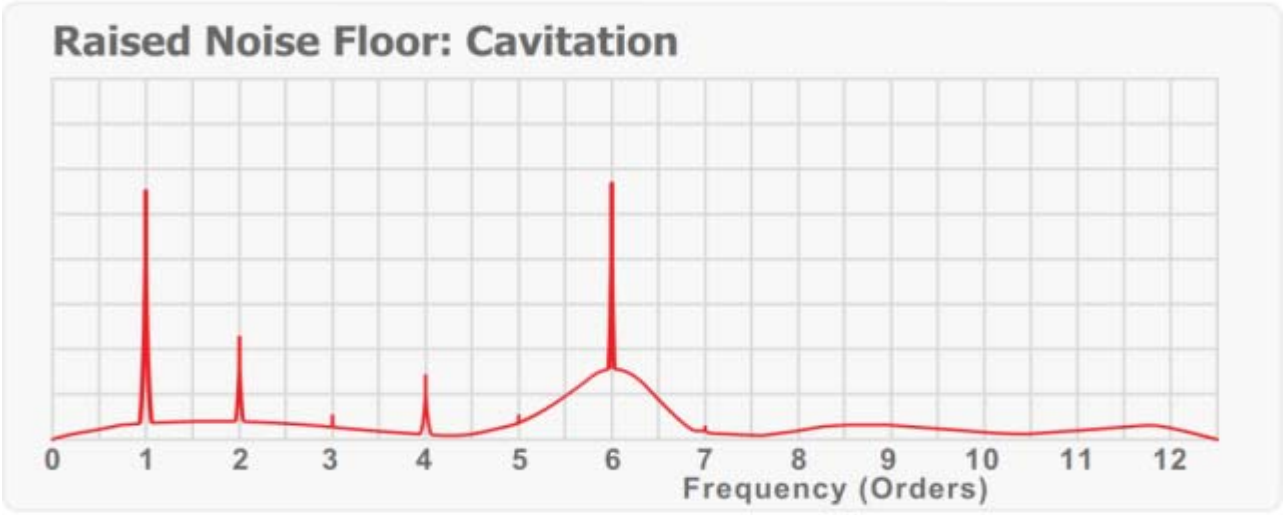
如果这个底部噪声抬起，可能是轴承磨损过大。如果噪声偏向于高频，可能工艺或流体噪声，有气蚀。

process or flow noise, with cavitation possible.

Smaller "humps" may be due to resonance (possibly excited by bearing damage, cavitation, looseness, rubs, or impacting), or closely spaced sidebands. A high resolution measurement (or graphical zoom and a log scale) may reveal whether the source is sidebands or a resonance. If you can change machine speed, the resonant frequency will not move – but the other peaks will. Sidebands will typically be symmetrical around a dominant peak, for example 1X, 2X, 2xLF (100 or 120 Hz), etc.

小的“驼峰”可能是由于共振（轴承损伤、气蚀、松动、摩擦、冲击）或边带过于接近。高分辨率（zoom 细化功能或对数谱）可以确认共振还是边带。如果你改变设备转速，共振频率不会移动，而其它的峰值会移动。边带通常在一个主动峰值两侧对称，如 1X、2X、2xLF (100 or 120 Hz)，等。





19.6 Things you should know: External noise 外部噪声

Symptoms: Non-synchronous peak 特征：非同步峰值

You will often find a peak in a spectrum that is difficult to explain. Before you jump to conclusions, you may like to rule-out the possibility that the vibration is from another

你常常会看到频谱中某个峰值很难解释。在妄下结论前，需要排除是否是其

machine or process. Vibration can be transmitted through the foundations and structural supports.

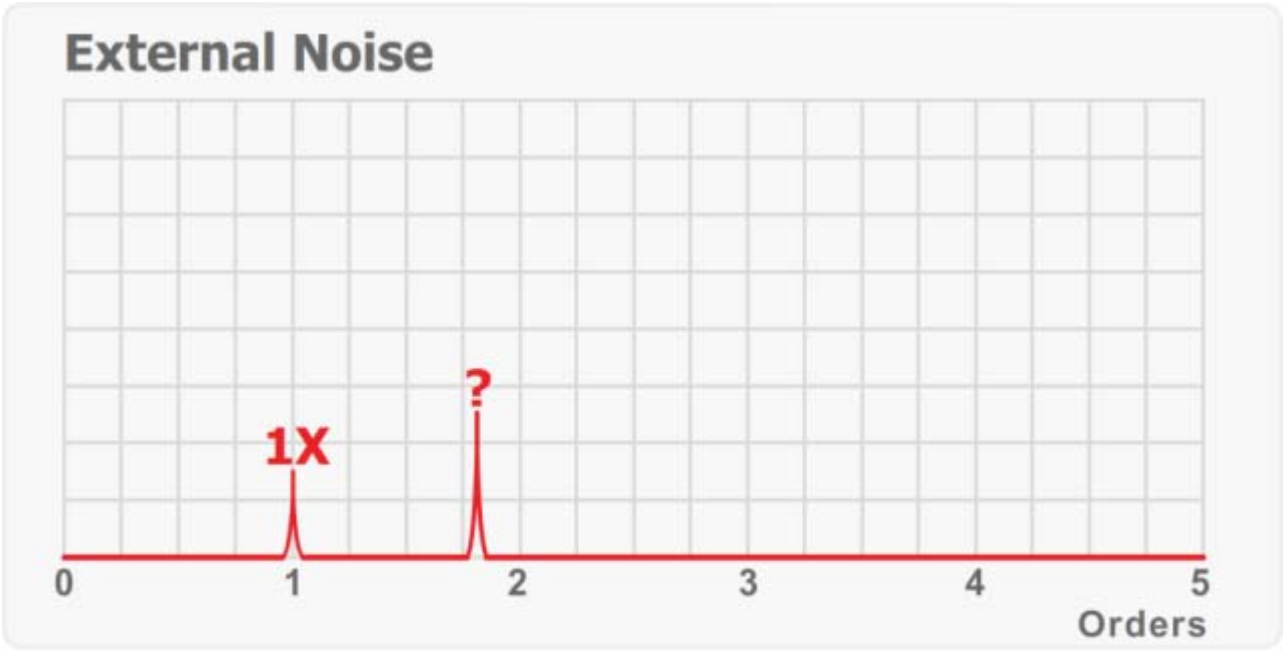
它设备或工艺的振动。振动通过基础和结构支架可以传递。

Peaks can also appear at a strange frequency because it is the sum of two other frequencies in the machine. Peaks can also be related to resonance – there could be a low amplitude source of vibration that coincides with a natural frequency and is amplified.

由于设备上其它频率之和，也会出现奇怪的频率峰值。峰值也可以与共振有关-低振动幅值正好和固有频率重合，被放大。

Note that vibration from external machines may course damage (through false brinelling) if the machine in question is often in stand-by mode.

注意如果设备在停机时，外来设备的振动可能导致损伤（布氏压痕）。


External Noise
1X
?
0
1
2
3
4
5
Orders