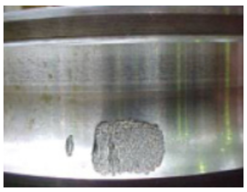
Electric Motor Problems & Diagnostic Techniques

EMERSON

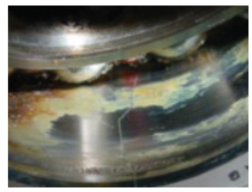
Electric Motors Drive Today's Factories

Abnormal Loading



Brinelling

Mounting Problems



EDM or Fluting

Lubrication Problems

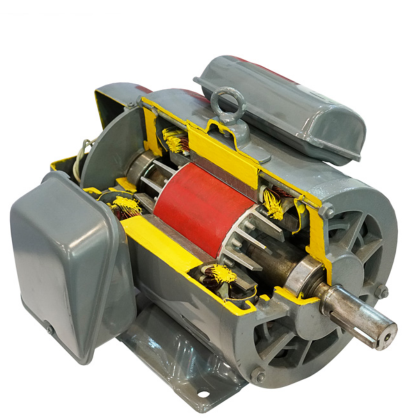
In today's industry the workhorse that drives nearly all pumps, gearboxes, fans, etc. is the 3-phase AC motor. Praised for its simplicity and durability, it often drives machinery 24/7, year after year. Although reliable, issues such as mounting problems, lubrication failures, overloading and other issues can shorten service lifetime.

When electric motor problems are detected early, operational conditions can sometimes be altered to return the machines to an efficient state and prevent further damage:

- Rate of failure varies from one application to another.
- Operators must understand failure modes and potential for failure for each machine.
- Criticality of application factors into how alarms are assigned.

Important factors in the lifespan of the AC motor:

- They must be cleaned regularly to prevent overheating.
- Insulation temperatures exceeding the motor's rated value will cut the life of the insulation in half for every increase of 10°C.



Mechanical Problems

EDM or Fluting

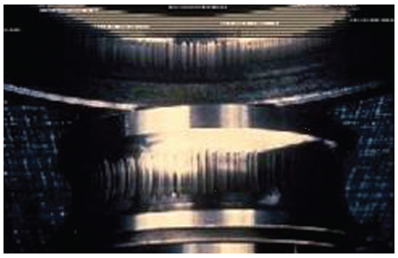
Fluting is caused by one of the following:

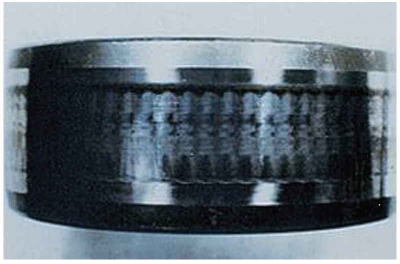
- Electromagnetic discharge (caused by the motor)
- Electrostatic discharge (belts, cylinders, etc.)
- External voltages (VFD, welding, etc.)

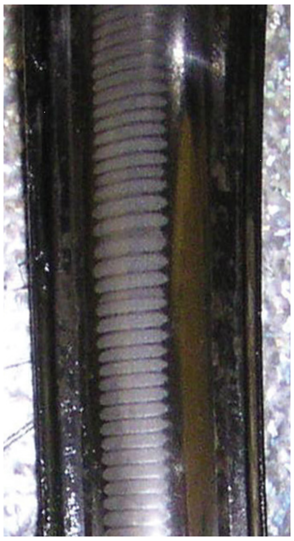
Electric discharge can cause pitting in rolling elements as charges arc through the lubricant film from the rotating shaft to ground. This pitting releases small fragments of material into the oil showing up as high particle counts, high ferrous density and wear debris. This promotes accelerated wear on bearings and other moving parts.

Fluting is a typical problem for large size motors (>200KW), VFD motors and vertical motors.

The appearance of the "washboard" patter is very common.
The difference between brinelling and fluting is that this pattern can be found all over the bearing (typically outer and inner race) while brinelling will typically manifest itself in the loaded zone.







Group	Testing for AC Motor Faults	Motor-current analysis	Motor-flux analysis	Vibration analysis	Oil analysis	High potential (HIPOT - AC or DC)	Step voltage	Surge comparisson	Capacitance-to-ground	Resistance-t-ground (megohmmeter)	Polarization index (PI)	Dielectric absorption (DA)	Phase-to-phase resistance	Phase-to-phase inductance	Online power quality
Stator	Phase-to-ground fault									X	X	X			
	Damaged or Contaminated Insulation								X	X					
	Turn-to-turn, coil-to-coil, and phase-to-phase faults		X					X					X		
	Open phases		X					X							X
	Ground-Wall Insulation					X	X	X							
Rotor	Broken/cracked rotor bars and rotor casting voids	X	X	X											
	Static and dynamic rotor eccentricity and air gap	X	X	X										X	
Power	Poor connections												X		
	Harmonic distortion														X
	Phase Imbalance		X												X
	Faulty capacitors in circuit													X	X
	Power condition, health, load and energy profile														X
Non-Electric	Bearing faults			X	X										
	Rotor shaft misalignment			X											
	Mechanical Imbalance			X											
	Degraded or contaminated lubricant				X										
	Oil whip, Oil whirl			X											

Electric Discharges

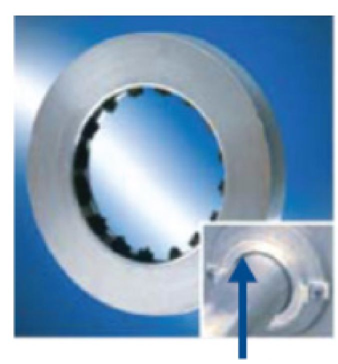
Even small currents may have a big effect. Electric discharge can be measured by checking the shat voltage and current amplitudes. The shaft voltage is often lower than 0.5V (when greater than 3V, the appearance of the "washboard" pattern is very likely). More important is the amplitude of the current and if it is a fluctuating or spiking current, or a constant flowing current.

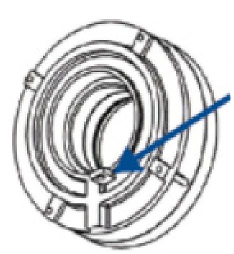
The effects of electric discharge may be managed by grounding of the shaft or the use of ceramic bearings.

Caution: when insulating motor bearings, other bearings driven by the motor can fail due to electric discharge. A grounding system is recommended.

The flow of current coming from the rotor to the stator can damage every bearing if countermeasures are not implemented.

Isolated Bearings



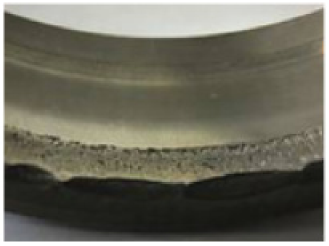


Gounding Brushes

Grounding Color

Abnormal Loading

Abnormal loading typically occurs when the dynamic load of the bearing is exceeded. Any load greater than the design of the bearing will cause accelerated failure. Most ball or roller bearings (common in AC motors) are not good in handling large axial forces or severe misalignment conditions. A ball bearing has a limited range of dynamic load due to the small contact area. Several failure patterns exist, but in general there will be flaking of the surface where the load is inappropriate.

Mounting Problems

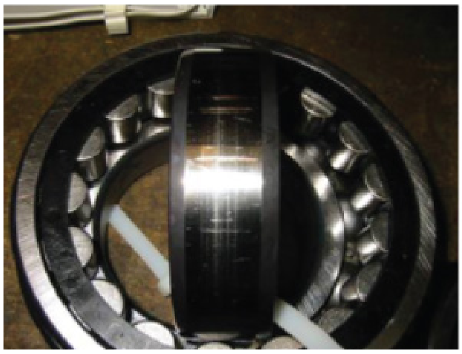
Improperly mounted bearings may function well for a while but will eventually fail earlier than their design life. Improper fit of the motor bearing can result in wear between the inner race and motor shaft or the outer race and motor housing. This is very detrimental to the motor and can result in a much shorter lifetime or even catastrophic failure.

Indications of sliding wear due to mounting problems can occur on the inner and outer race. Other patterns of improper fit are rusty markings on either or both of the inner and outer race.

In most cases vibration analysis will detect the abnormal looseness generated by this defect.

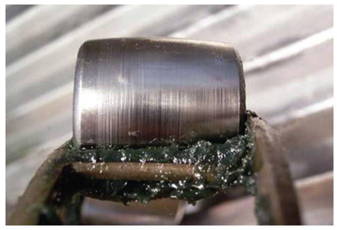
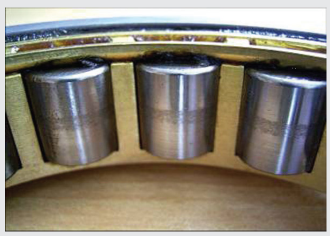
Brinelling

Brinelling typically occurs when there is a background vibration while the motor is not running. This will cause the lubrication film to be pushed away, causing a cold-welding action between the roller and raceways. The surface gets damaged and will result in progressive flaking. This can be avoided by isolating background vibrations and regularly switching the motor with a backup motor. Any static overload or severe impact (during mounting of a bearing) can also cause brinelling.


Lubrication Problems

It is very important that the correct grease and the correct amount is used for each motor. This is vital to prevent damage to the motor bearings and other components. Too much or too little grease is a very common problem. In either case the motor can be damaged by either "popping" the seals with too much, or running the bearing dry with no grease. Ultrasonic tools can help determine the correct amount of grease to apply.

This bearing has a well-defined colored raceway. The inner race is still intact but the effect of high heat can clearly be seen. These elevated temperature are typically caused by the bearing running with boundary lubrication or with no grease.  	After being in service for a short time, elevated noise levels were detected. After replacement of the bearing, markings were found on the rollers indicating wrong selection of grease for this particular application. 
Having excessive amounts of grease can eventually result in a chemical reaction and breakdown of insulation on motor windings. Dirt can also become trapped in grease on windings and can cause shorting and overheating. The bearing housing contains the recommended grease but is filled beyond capacity. The bearing ran hot during operation because of the high volume of grease. 	This bearing ran for only a few hours at high speed (6000 RPM) with the bearing housing completely filled with grease. After a short time, abnormal sounds were detected and the bearing was dismantled. Cause: under-loading of the bearing together with massive amounts of grease caused sliding of the rollers. 

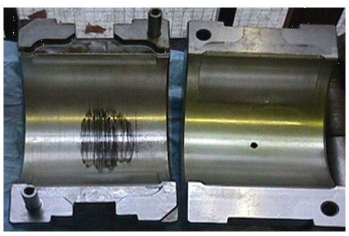
** These are typically accepted units, but may be user defined.*

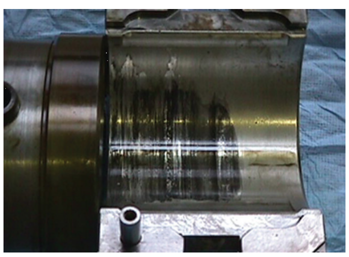
Sleeve Bearings

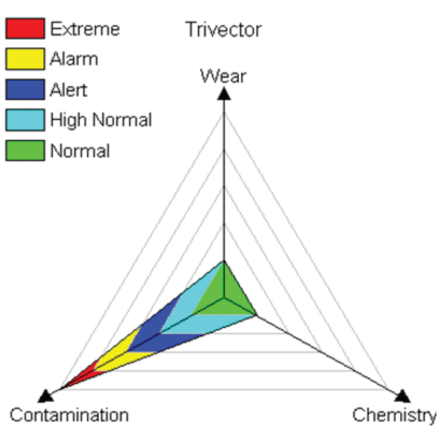
Most large AC motors are equipped with sleeve bearings. Although very reliable, some specific problems can exist. The most common problem is direct contact between the rotor shaft and sleeve bearing, causing abnormal vibration, oil discoloration and melted Babbit metal particles in lubricating oil. Causes for this type of damage include:

- Abnormal loading
- Incorrect lubricant or sudden changes in viscosity
- Severe misalignment

Vibration and oil analysis are the main technologies to assess the condition of the motor's sleeve bearings.



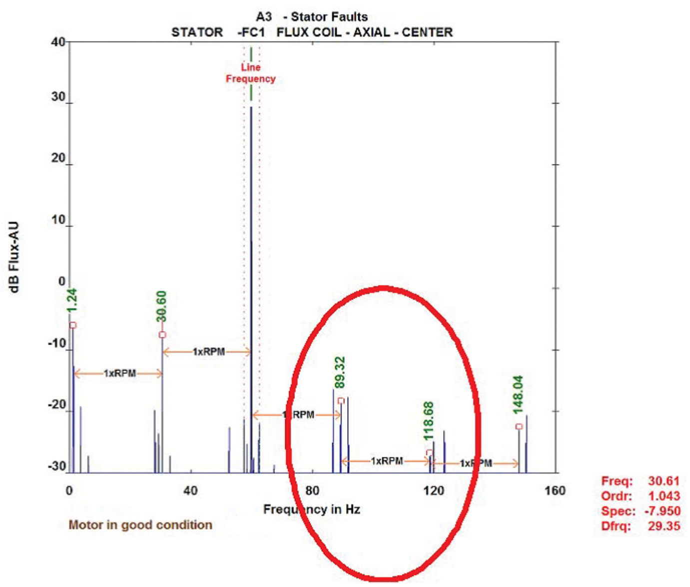


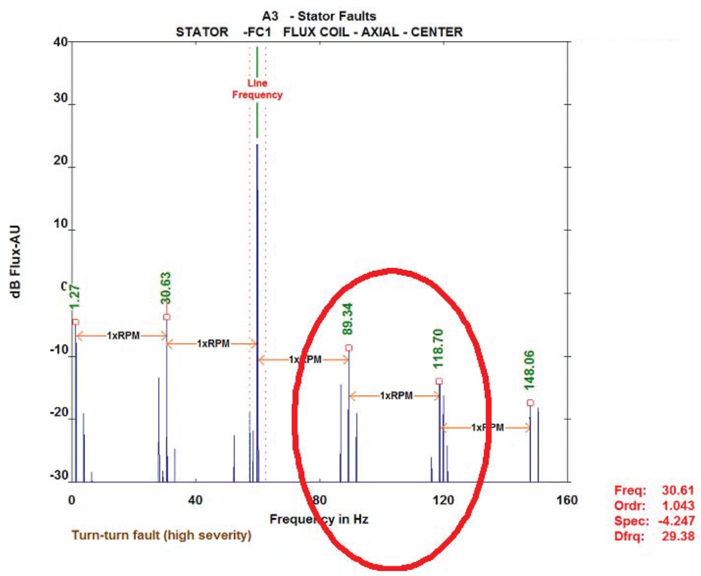


Babbitt (lead, tin, antimony alloy) contaminates oil after sleeve bearing wipe.

Low Frequency Stator Flux Analysis

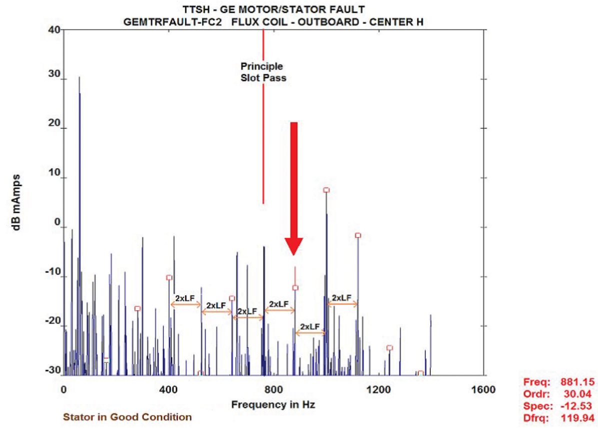
One of the first faults a winding will encounter is turn-to-turn shorts. These faults will migrate into phase-to-phase or phase-to-ground shorts. In the plots below, the labeled peaks occur at running speed sidebands about line frequency. These peaks occur at frequencies associated with non-symmetrical winding faults. The amplitude values of the running speed sideband peaks in the faulted stator condition are significantly larger (also the difference between the line frequency amplitude and sideband amplitudes are smaller) than those found for the stator in good condition

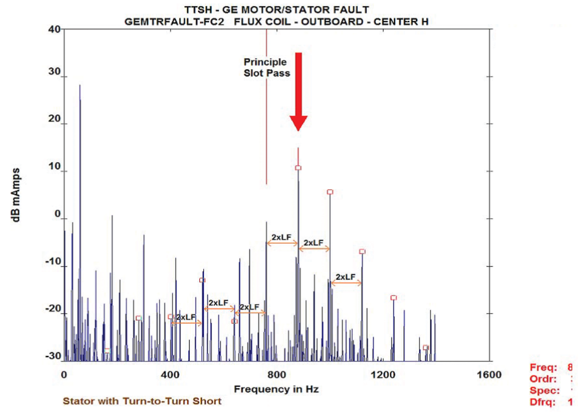




High Frequency Stator Flux Analysis

Electrically related anomalies can be seen with changes in the flux frequency amplitudes about the electrical family of slot pass frequencies. These frequencies occur as in vibration except that the family of peaks is offset by line frequency. The principle slot pass (PSP) frequency appears at number of rotor bars or stator slots times the running speed of the motor, minus line frequency ((SLOTSxRPM) – LF). In this equation, SLOTS can be either rotor bars or stator slots. Just as with vibration, there is a family of peaks comprised of sidebands at twice line frequency. The slot pass family of peaks can be represented as [((SLOTSxRPM) – LF + Nx2xLF]. In this equation, “N” is an integer such that it equals 1, 2, 3, 4...Any of these peaks can also be modulated by the running speed of the motor.





Flux measurements should be taken monthly to measure any deviation of the electromagnetic field. Generally speaking, while rotor defects on AC motors progress slowly, stator faults can develop rapidly. Therefore ,frequent monitoring is recommended.

Problems such as uneven airgap, insulation problems, and deformation of the stator will result in the rotating magnetic field showing inconsistencies.

These inconsistencies appear in a spectrum as slot pass and/or 2x line frequency from airgap eccentricity.

Stator-Related Issues

Stator-related failures account for a large portion of all electrical problems on AC motors. Most stator faults are caused by insulation breakdown which leads to winding failure.
They include:

1. Open windings
2. Phase-to-ground
3. Phase-to-phase
4. Turn-to-turn short

If the motor keeps running with stator faults, a high current will flow through the windings where the problem is located. This high current generates heat which further degrades winding insulation and causes short-circuit between the windings and eventually products a phase-to-ground failure. The motor will fail quickly after that.

Cause of insulation breakdown are mainly due to overheating which results from:

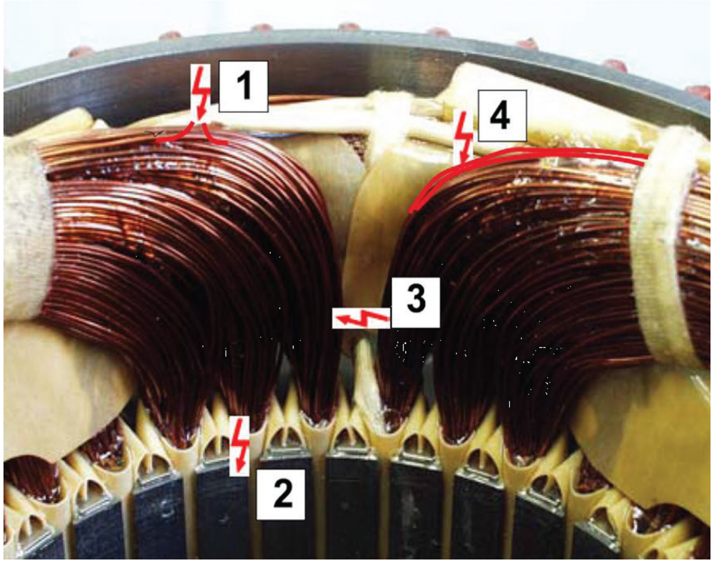
- Voltage imbalance (imbalanced external loading)
- Loose connections in the windings
- Loose windings
- Restricted airflow
- Motor overload
- Damaged, contaminated or aged winding insulation

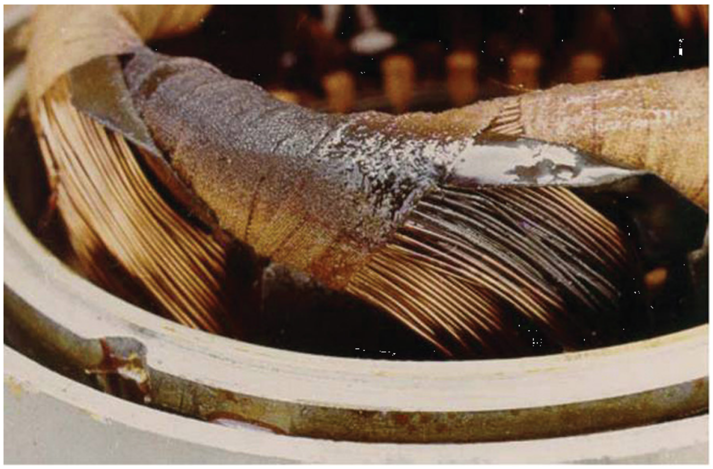
An electric motor be definition products magnetic flux. Any small unbalance in the magnetic or electric circuit of motors is reflected in the axially transmitted fluxes. Electrical characteristics within a motor will change due to asymmetries in the rotor or stator windings, as will the axially transmitted flux.

Broken rotor bars as well as unbalanced phases and anomalies in the stator windings such as turn-to-turn phase-to-phase and phase-to-ground shorts can product electrical asymmetries.

Axially transmitted flux measurements can be acquired with a flux coil mounted axially on a motor. A trend of certain magnetic flux measurement frequencies will indicate electrical asymmetries associated with the rotor and stator windings.

The majority of the peaks in a flux coil spectrum occur at frequencies which have some relationship to running speed. Changes in these speed related peaks provide strong indication of electrical faults such as broken rotor bars, unbalanced voltages and stator insulation breakdown.





Stator Looseness

If the windings are not firmly attached in the stator, this looseness may cause the windings to vibrate at 2xLF (100Hz in Europe or 120 Hz in the US), or very rarely at 1xLF, especially during startup. Loose laminations are another rather rare problem which occurs most often during startup.

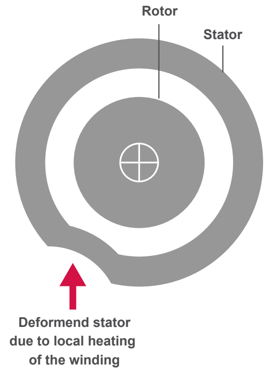
Uneven Airgap (Static Eccentricity)

An uneven airgap occurs when the gap between the stator and rotor is not uniform over the whole motor (360o). This can be caused by one or more conditions:

Cause of insulation breakdown are mainly due to overheating which results from:

- The problem is viewed at 2xLF peak in vibration or at slot pass frequencies modulated by 2xLV (vibration and current)
- A deformed stator (for example, caused by defective insulation which results in uneven heating)
- Soft-foot condition related to mounting
- An eccentric stator

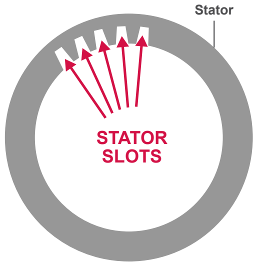
Localized hearing will sometimes deform the stator. Because of this deformation, variations of distances in the air gap where the heating exits will occur. However, most stator deformation is due to soft foot or improper mounting.



Stator Fault Analysis

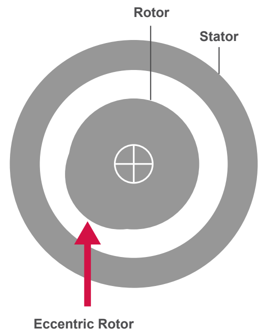
Stator fault and voltage unbalances can be determined by trending certain frequencies obtained in a flux spectrum. Provided a baseline flux spectrum is collected while the motor is in a good condition, stator-related faults can be estimated by comparing certain frequencies from flux spectra to that of the reference (baseline) flux spectrum. Analysis of flux measurements can be performed using spectra at two different frequency ranges:

- A low frequency flux spectrum (0-200Hz/3200 lines)
- A high frequency flux spectrum (0-3(6)kHz/6400(12800) lines)



Rotor-Related Issues

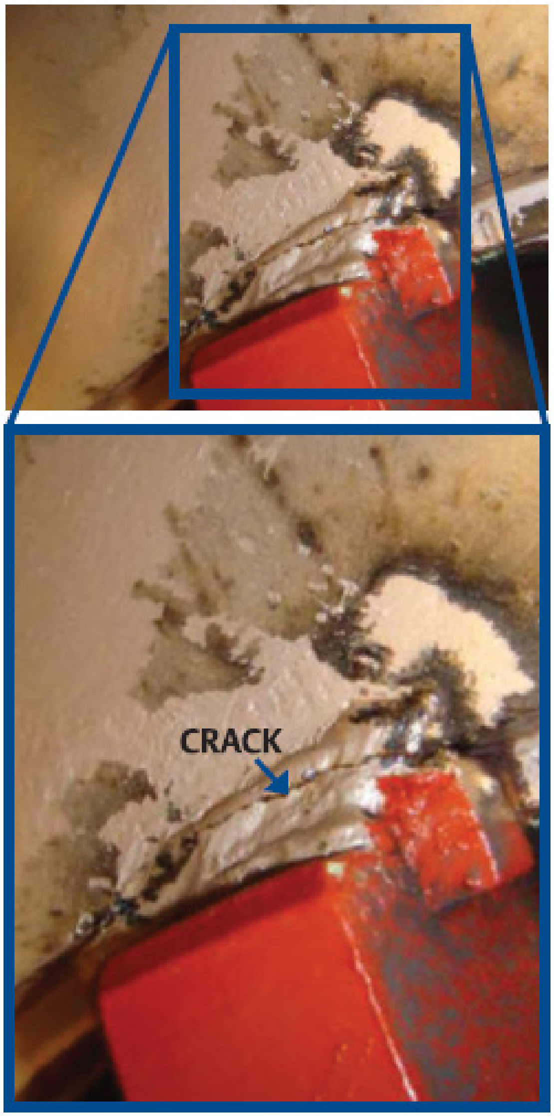
The most common problem with rotors is broken rotor bars. It is very important to detect a broken rotor bar, as I can result in complete failure of the motor. Large motors (+90kW) are especially prone to this type of defect. High in-rush currents when starting can damage the rotor bars, especially if the motors start often. If left undetected, rotor rub is also possible, resulting in complete motor failure.



Eccentric Rotors

Dynamic eccentricity can occur in a rotor that is not perfectly round. This most commonly occurs from a defect in the rotor bar(s).

Dynamic eccentricity is most commonly viewed as a 2xLF peak in vibration, or at slot pass frequencies modulated by running speed (vibration and current).



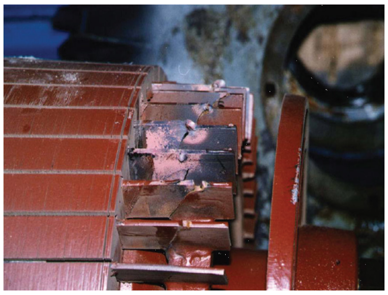
Indicators of Rotor Bar Flows

- Fluctuating current draw
- Modulating sound
- Increase of 1xRPM vibration plot component (results from uneven heating of the rotor causing an eccentric rotor resulting in imbalance)
- Sidebands occur about the 1xRPM component at slip frequency x number of poles

Before diagnosis it is important to have the motor running at 60% or higher load to ensure enough current is flowing through the rotor bars.

A common technology used to detect broken rotor bars is electric current analysis. This technology requires a measurement of current using a portable current clamp. An FFT is calculated from the associated electric current waveform. Analysis of this spectrum is used to determine the ratio between the line frequency peak and sidebands. Any ratio less than 40dB is cause for concern.

Note: larger AC motors (200kW+) which have frequency startups will expose the rotor to high in-rush currents, creating a higher chance for rotor-related problems.



Rotor Bar Faults

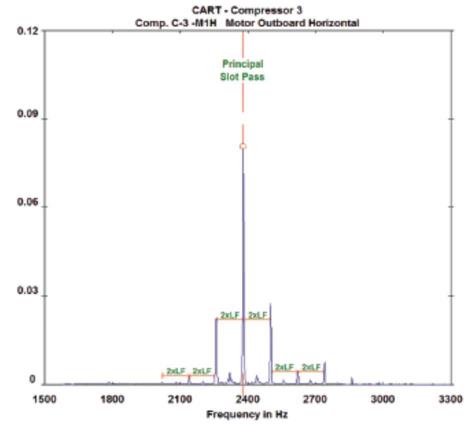
- Broken rotor bars
- High resistance joints
- Voids in aluminum cast rotors
- Broken end-ring
- Loose rotor bars

Condition	Difference
OK	+ 54dB
Warning	54 - 45 dB
Alarm	45 - 40 dB
Failure	- 40 dB

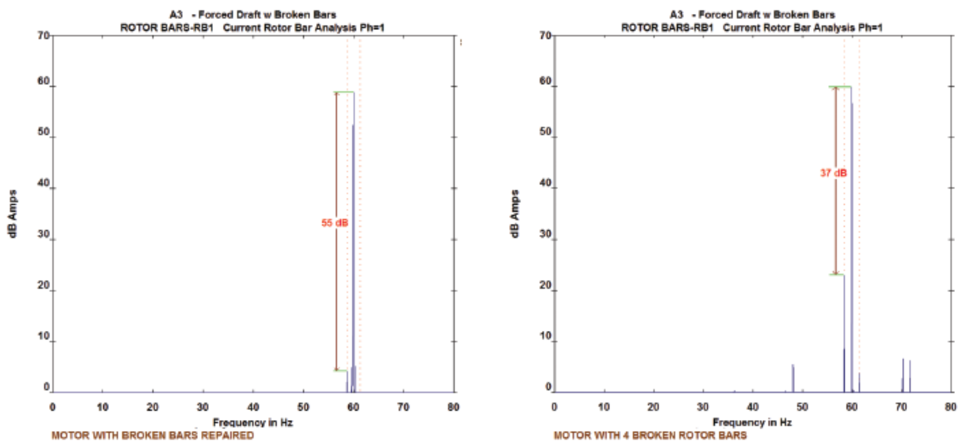
Declining difference in the dB levels indicates the fault level severity of the rotor bar.

Slot pass frequencies appear as a family of frequencies (peaks) modulated about a set of primary frequency occurring at the number of rotor bars (or stator slots, or both) times running speed. These modulated frequencies occur as 2xLF (static eccentricity) and/or running speed (Dynamic eccentricity).

For 2 or 4 pole motors, high resolution vibration measurements (for example 200Hz bandwidth / 3200 lines) can distinguish between 2xLF or a 2x (or 4x) running speed peak.



Use Electric Current Analysis to Determine Rotor Bar Problems and Severity



PeakVue Technology for Rotor Bar Fault Detection

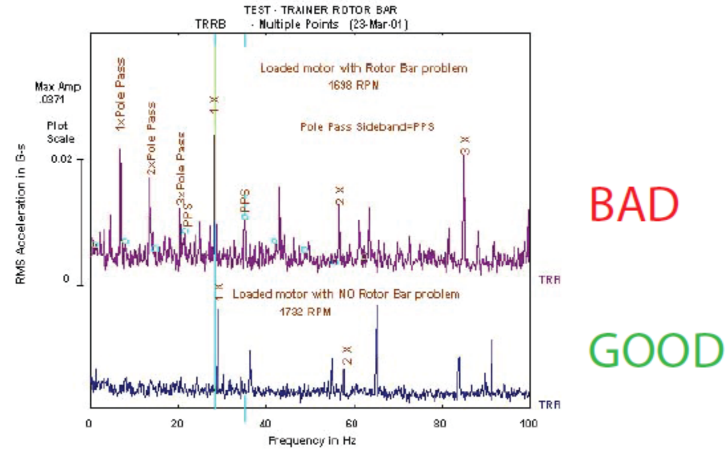
PeakVue spectral data can be used for simple and easy surveillance of rotor bars for fault detection. This is a vibration measurement which can be done with normal vibration monitoring equipment as a quick check to determine if a rotor bar problem exists. If a problem is found, further diagnosis should be done using electric current analysis.

The signature indicative of rotor bar faults shows:

1. Activity at pole pas frequency (# poles x slip frequency) with harmonics.
2. Activity at motor running speed side banded with pole pass frequency.

PeakVue Spectral Data for Motor With and Without Rotor Bar Faults

PeakVue signatures may be used for surveillance in identifying probably faults, but do not provide a reliable level of severity of the fault. Analyze the current to assess fault severity.



Motor Analysis is Used to Improve Profitability in Every Major Industry in the World

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