

A Summary of AC Induction Motor Monitoring

By Dr. Bob Jones

Purpose

This paper summarizes the methods of analyzing an AC motor's electrical and mechanical condition based on both electrically induced mechanical vibration and electrical signals detected with a clamp on ammeter. It will also provide the Microlog user with suggestions and hints on analyzing motor problems. The author has applied these techniques to motors from 5 to 700 HP.

Mechanical Vibration

Using a standard accelerometer placed on the bearing cap, several unique mechanical vibration signals will be generated by electrical faults in the motor circuits. One of the more common is a signal at twice line frequency. If the line frequency is 60 Hz, this signal will be at 120 Hz or 7200 CPM. If the line frequency is 50 Hz, the signal will be seen at 100 Hz or 6000 CPM. Care must be taken when testing two pole motors (3600 RPM or 3000 RPM) that the signal is not twice rotating speed instead of twice line frequency. Verify the frequency by placing the cursor on the signal and on the Microlog pressing the 1x RPM button or Set Speed with the PRISM software.

This two times line frequency signal will be created by any of the following faults either singly or in combination:

An Uneven Air Gap Between The Rotor and Stator

As the poles of the motor pass the narrow gap, the magnetic pull is greater versus 180 degrees on the opposite side where the gap is the widest. The number of poles (motor speed) does not change the results, an uneven air gap will result in a velocity spectrum signal at 2x line frequency for any size or speed motor.

The cause of this uneven air gap is often a 'soft foot' caused by an uneven base plate. As

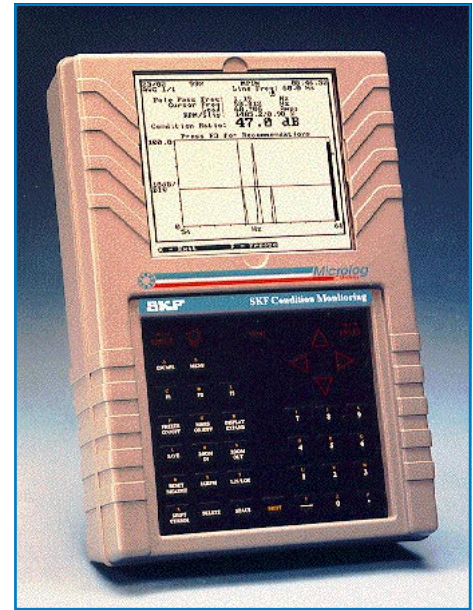


Figure 1. The SKF Condition Monitoring CMVA55 Microlog.

the motor is mounted to the base, the motor housing and stator are distorted, resulting in the uneven air gap between the stator and the rotor. Some empirical data seems to indicate that the twice line frequency signal will appear when the gap clearance exceeds 10% variance. Soft foot can be confirmed by loosening and tightening one bolt at a time with the motor running while observing the spectrum on the Microlog. When the soft foot is loosened, the velocity signal at 2x line frequency will decrease, then increase as the nut is tightened. At the next shutdown, this foot should be shimmed to the same plane as the others.

Damage to the Stator Windings or Insulation

There are numerous causes to stator damage: manufacturing, environment, or flaws in the insulation. Any damage to the stator will again create an uneven magnetic field around the rotor. This uneven field will in turn generate an uneven pull on the rotor regardless of the

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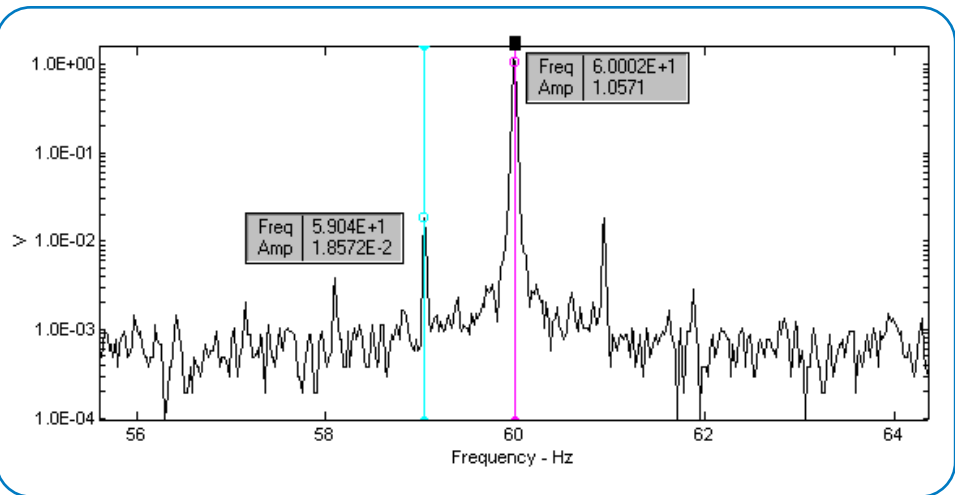


Figure 2. This is the spectrum from a damaged compressor motor that had 5 broken rotor bars and a damaged end ring. $\text{Log } 0.018572/1.0571 \times 20 = 35.1 \text{ dB}$.

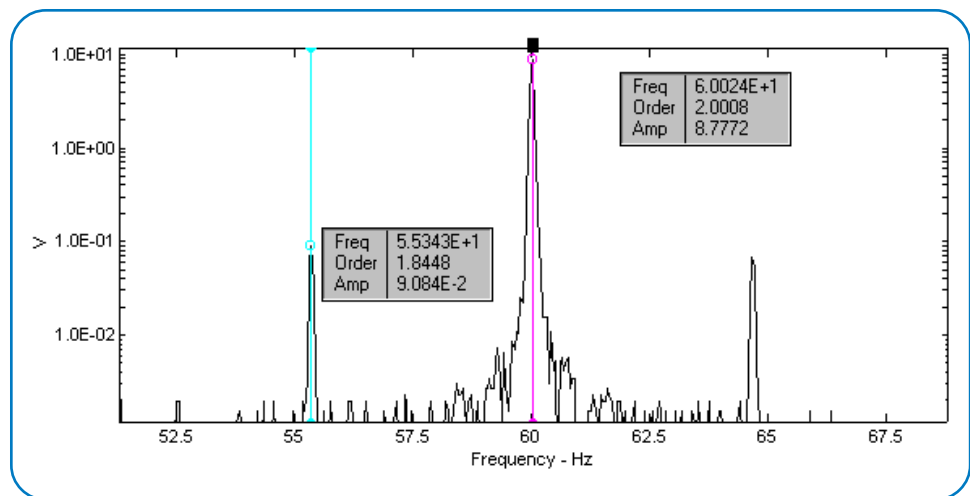


Figure 3. Motor in lab with four cut rotor bars and broken end ring. $\text{Log } 0.0908/8.777 \times 20 = 39.7 \text{ dB}$.

motor speed and cause a mechanical vibration at twice line frequency.

It is often possible to locate the area of damage with either an infrared or thermal detector. Often there will be an area on the motor housing where the surface temperature will be 20–30 degrees hotter.

A damaged stator will also generate a mechanical vibration signal at a frequency equal to the number of rotor bars times the rotation speed. Again, in the area of stator damage, the magnetic field will be weakened and therefore stronger 180 degrees away. As each rotor bar passes this area of higher strength, the bar will mechanically pulled in that direction.

Typically induction motors will have between 45-55 bars in the rotor but this can vary greatly depending on the manufacturer. For this reason, it is very

important when troubleshooting a motor vibration, to set the F_{max} at least 100 times rotation speed. Please note this F_{max} is for **TROUBLESHOOTING** only.

Since the number of rotor bars can vary greatly, it is most important to establish a procedure that anytime a motor is down for repair, the actual number of rotor bars are counted and recorded for future reference. It is also important to record the full bearing model number so that the bearing frequencies can be accurately determined when analyzing for bearing degradation.

The user can verify that the vibration is electrically induced by shutting off the motor while observing the velocity spectrum in the analyzer mode. The moment the power is removed, the distorted magnetic field is instantly collapsed and the twice line signal will disappear. If the signal does not disappear but slowly degrades, then the

user knows there is some type of mechanical problem. When setting up the analyzer, use 100 lines, 0 averages and an F_{max} of 2000 Hz to provide a fast cycle time.

If you are using a CMVA55, and there is damage in the stator, then the signal will also be seen in any enveloped acceleration spectrums and will most certainly generate harmonics of the fundamental.

There is no agreed upon amplitude of concern if the twice line frequency signal is present in the velocity spectrum. It is generally agreed that it is not desirable to have any signal at 2x line frequency, however it is often seen. Generally accepted limits are between 0.04-0.06 IPS at 2x line frequency. One case using enveloped acceleration, where the 2x line frequency was trended over six months, showed an increase from 0.4 Env G's to 1.6 Env G's, when the motor

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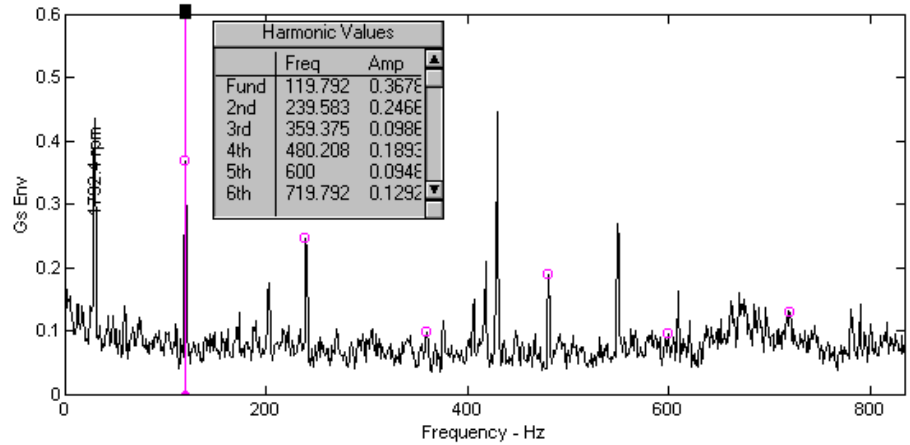


Figure 4. Twice line frequency with harmonics using Env G's.

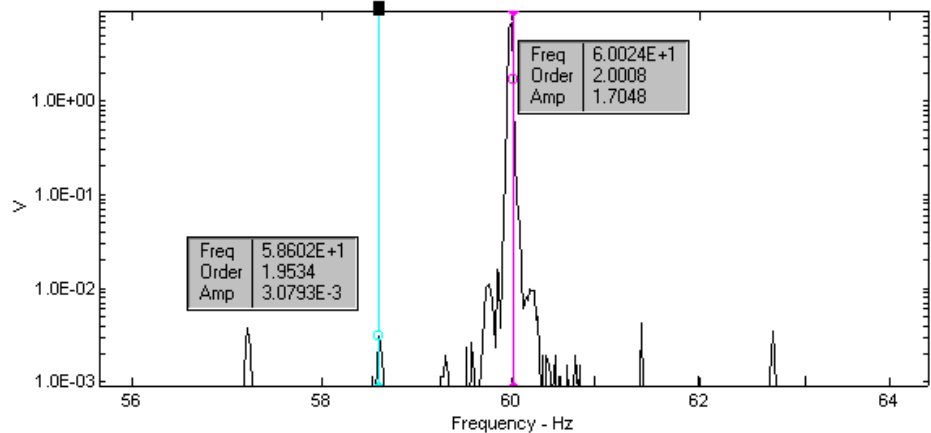


Figure 5. Motor in lab with no damage. $\text{Log } 0.003079/1.704 \times 20 = 54.8 \text{ dB}$.

failed. However after the motor was repaired, the amplitude started at 0.8 Env G's and has remained fairly level to the present.

The first occasion was most probably a damaged stator with soft foot. After repair the soft foot is still present, though somewhat different because of a different torque on the mounting bolts.

Sidebands

As in most vibration signals, the presence of sidebands around fundamental frequencies is a measure of increasing severity as the sidebands increase in number and amplitude. Some of the sideband energy that may be seen will be pole pass frequency, (number of poles times slip) and slip, (nominal speed minus actual speed). At the rotor bar pass frequency (number of rotor bars times actual motor speed) it is possible to see sidebands of 2x line

frequency. In troubleshooting, the user may find it necessary to increase the resolution to either 1600 or 3200 lines of resolution to be able separate these sidebands. By starting at 400 lines and zooming with the Microlog in the analyzer mode, the existence of this energy can be verified.

Analysis of AC Motor Current

The technique of evaluating the motor condition by performing an FFT of the motor current has been verified many times over the past 6 years. And, although it is often referred to as a method to detect broken rotor bars, the fact is that it detects abnormal high resistance in the rotor circuit. In other words, bad solder joints, loose connections and damaged rotor bars. The users of the new CMVA55 will note that all the mathematical functions are

performed automatically by the Motor Current Monitoring Wizard™ which quickly provides the user with the information he needs. In all the cases, the motor must be at 70-75% load.

For users of other Microlog models, the following is a quick review of the methodology. From either the route mode or analyzer mode, the data is collected using the point setup outlined in the instruction manual or user notes. If there is a fault in the rotor circuit, then the spectrum will have two prominent features when displayed with the 'Y' axis as a logarithmic function. At 60 Hz, line frequency, there will be a large spike. To the left at a distance equal to the rotor slip times the number of poles will be another spike of energy. These spikes can be labeled 'A' and 'B'. Note that the amplitudes will have to be obtained from the software display because it is necessary to use amplitudes to four decimal places.

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SKF Condition Monitoring Area Centers

North and South America

4141 Ruffin Road
San Diego, California 92123
USA
Telephone (619) 496-3400
FAX (619) 496-3531

Europe, Middle East, Africa

Postbus 2091
5300 CB Zaltbommel
The Netherlands
Telephone (+31) 418-541010
FAX (+31) 418-540455

Asia, Pacific

153 Gul Circle, Jurong
Singapore 629610
Telephone (+65) 861-6922
FAX (+65) 861-3044

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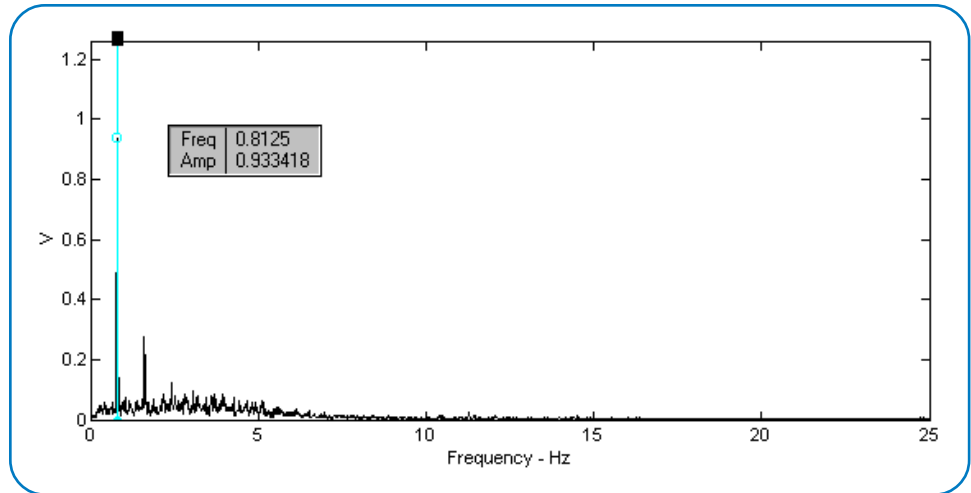


Figure 6. Enveloped AC motor current, slip frequency of 0.8125 generated by 5 broken rotor bars and a damaged end ring. Ratio of pole pass frequency amplitude to overall amplitude is 63%.

To determine the condition, perform the following calculation:

- Log (A/B) times (20) = amplitude in dB.
- 54-60 dB = Excellent
 - 48-54 dB = Good
 - 42-48 dB = Moderate
 - 36-42 dB = Cracked rotor bars or other source of high resistance.
 - 30-36 dB = Multiple sources of high resistance.
 - < 30 dB = Severe damage

Note that this chart applies to rotor circuit damage and that the motor must be under at least 75% load. The amplitude of the pole pass frequency is not linear with respect to reduced loads and if these amplitude are used, the results will not be accurate. The examples in Figures 5 and 6 provide illustrations from both good and bad motor circuits.

Observations of Other Motor Problems

High efficiency induction motors obtain their higher efficiency, and use less electricity, by two methods- a smaller air gap and thinner insulation on the windings. If the owner installs these motors on the same transformer circuit that has DC motors installed, it is possible for the DC motor silicon control rectifiers (SCRs) to back feed onto the AC circuit and induce high voltage spikes into the motors. The reduced insulation will rapidly deteriorate and lead to a reduced motor life. Field results have shown as much as a 50% reduction in the life of the motor due to such an occurrence.

DC motor problems will be seen at the SCR firing frequency, 6 times line frequency. If this

frequency is seen, check connections, SCR's, control cards, and fuses.

Enveloped AC Motor Current

When the motor current from a motor with a damaged rotor circuit is enveloped, the resulting spectrum will show energy at the actual pole pass frequency. For example, at 0.8 Hz, not as a sideband of the 60.0 Hz signal or 59.2 Hz. Initial research has shown there is a relationship between the pole pass frequency amplitude as a ratio to the overall amplitude of an FFT spectrum taken with an F_{max} of 25 Hz. Typically, in a good motor, this will be a very low amplitude signal and will not be seen in an enveloped spectrum. So, the frequency will have to be calculated to locate it. Initial data has shown a good motor will have a ratio of 5% or less but as damage increases, this percentage will increase. See the example with broken rotor bars (Figure 6). Also harmonics of slip frequency are additional indicators of damage. Initial testing has shown this to be a very sensitive method and will detect very early degradation in the rotor circuit.

Technology Facilitates Induction Motor Analysis

By utilizing velocity and enveloped acceleration in conjunction with motor current analyses, users can dramatically increase their success in trending, analyzing, and evaluating the condition of AC induction motors. Thanks to data collectors like the Microlog CMVA55, plant maintenance and reliability personnel can easily and successfully detect electrical and mechanical faults that lead to unexpected downtime.