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Confirmation and Correlation: EMT and Vibe for Healthy Motors

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Meggers old and new.

Electric motor maintenance has come a long way in the last 25 years. A quarter of a century ago one of the primary methods for testing motors was "megger" testing. The name of the test came from the brand name of the instrument used to perform the test, Megger®. A mega-ohm meter is used to test insulation resistance, mega-ohm meters are generically referred to as "meggers," hence the adaptation of the term as the accepted name of the test method. For many years Megger® testing of motors was one of the few, widely-used modes of motor testing in the industry.

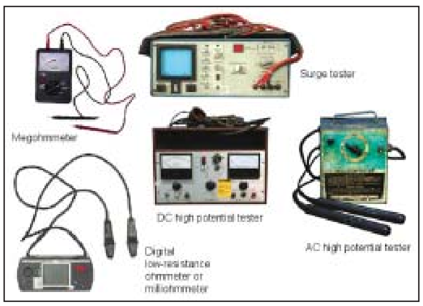
There were other test methods available. Some of them, however, were a bit more esoteric in nature, or performed mainly in motor rewind shops and motor manufacturers facilities, not on the plant floor. Many of these test methods, such as monolithic rotor bar testers and LCR bridges required the motor to be disassembled, allowing rotors and stators to be tested separately. This type of testing still held value, but they took motor troubleshooting and testing out of the hands of the facility maintenance personnel. Today the choices are much better, and assessment of motors and associated rotating assets can be done quickly and efficiently, if the right technologies are implemented.

So, let's take a look at how we arrived at this point in the motor testing timeline by discussing what methods are available, how they work, and how they can be combined for superior results.

In the late 1980's several manufacturers debuted motor test set platforms with combined capabilities of previously available individual instruments. These developments were driven by advances in condition monitoring requirements at Oak Ridge National Laboratories where the need existed to test rotating equipment located inside of containment areas. One of the technologies developed was known as Electrical Signature Analysis (ESA). This testing method examines the current and voltage inputs from the motor circuit while the motor is in operation, allowing for fault identification from incoming power through to the rotor. ESA works because of the change in the rotor/stator air gap caused by several different modes of failure. The sister technology of ESA is Motor Circuit Evaluation (MCE), which tests the motor and its associated circuit while the motor is out of operation. Both of these test methods allow motors to be tested from their starter circuits. The difference between them is the data sets available from each type of test. At the advent of what we now call Electric Motor Testing (EMT), several testing products were available to perform either ESA or MCE.

The two modes of testing went by several names at first; Energized and De-Energized, Dynamic and Static, Online or Offline. In the mid to late 1990s, units came to the market that allowed Dynamic and Static testing with the same unit, with just a change in the components used to interface the motor circuit, depending upon which test was to be performed.

Vibration analysis recorder.



Various types of motor testers.

Vibration analysis is another testing method that gained ground in the world of reliability as ESA and MCE were being developed. The concept of vibration analysis is as old as the industrial revolution. Tor years, mechanics and even machine operators have been able to diagnose impending failure by touch or sound.

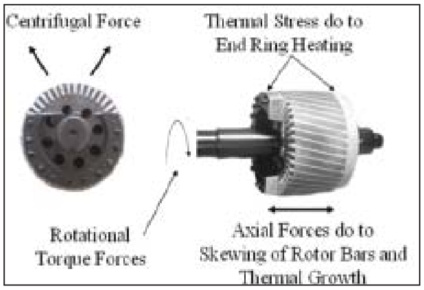
The old broom handle or screwdriver method was used to listen for impact on a bearing, or abnormal vibration. As far back as the 1950s, rudimentary vibration instruments were available for machine diagnostics, although limited it their application. These early instruments measured vibration velocity, and separating normal vibration from abnormal in rotating machinery was the greatest limiting factor. In the 1980s and 1990s, as advances were being made in microprocessor technology, the use of the Fast Fourier Transform (FFT) for spectral analysis made the analysis of collected vibration data easier to accomplish.

As technology continued to advance, the instruments used to collect and analyze vibration data got smaller and therefore more portable. Analysis software improved by leaps and bounds as well, and this helped move Vibration Analysis along as a more widely used testing technique as well. So these days, facility maintenance professionals have many choices in their toolbox for motor testing.

However, one of the limiting factors in wider application of each of these technologies is a deeper understanding of how each works. Even with the proliferation of reliability centered maintenance across all industry sectors, there are still many maintenance professionals who aren't as familiar with what they have available to help them monitor the condition of rotating assets.

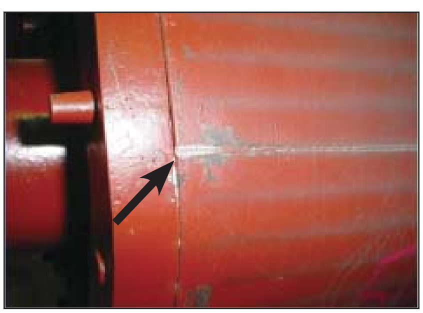
As previously stated, EMT is a hybrid of the two technologies that were initially known as ESA and MCE. The maintenance and reliability professional has two modes of testing to choose from; Energized or De-Energized, each presenting different data sets. Energized testing is intended to be applied to motors while they are in operation. This is especially valuable in applications where the motor requiring testing is in constant operation. The testing is transparent to the equipment. The voltage and current leads are attached to the motor circuit at the starter and measurements are made as the motor operates. The most useful data in energized EMT is pole pass frequency side bands, specifically their amplitude. It's from this data that rotor bar issues are discovered. Rotor bars that are aligned as they're supposed to be will present pole pass frequency sidebands of lower amplitude than those that are broken or otherwise not properly aligned. Additionally, other modes of failure can be detected utilizing energized EMT, both of an electrical and mechanical nature. For EMT to work in this manner, however, the rotor/stator air gap has to be impacted by the condition.

Changes in the air gap impact the electromechanical fields between the rotor and stator, and this distortion in sensed by the test instrument. Modern motor testers utilize a FFT to display the current and voltage waveform data in a frequency format, so the impact of air gap eccentricity can be more easily viewed. In order for mechanical faults to be visible however, there must be enough of an impact on the air gap that there is a detectable impact on the current waveform. Sometimes however, the fault may not be of sufficient magnitude for conclusive results with EMT alone.



Rotor stresses.

Vibration analysis on a motor.



The arrow indicates the end of the rotor bar where it connects to the end ring, The rotor bar has broken loose, and has been rubbing against the stator windings.

De-energized testing presents a completely different data set. Measurements are taken of motor circuit resistance, impedance, and capacitance. Higher than normal capacitance can help motor testing technicians discover dirty or corroded windings.

Impedance and resistance measurements can lead to discoveries regarding the health of the motor windings, or the circuit feeding the motor. The vast majority of electrical failures of motors begin with turn-to-turn shorts in the stator windings. Each individual winding of wire in the stator is intended to be electrically isolated from the others. High temperature conditions brought about by increased internal resistance or overloaded condition of the motor, lead to breakdown of the insulating material between individual windings. This, in turn, allows current to flow between the windings. Turn-to-turn shorts are revealed by measuring the amount of impedance on each set of windings and comparing them to one another. A certain amount of impedance imbalance can occur just because of inherent factors in the windings themselves, but higher than nominal impedance imbalance between phases is a telling sign of turn-to-turn shorts.

Vibration analysis often views the same conditions that EMT does, but analyzes it differently. Broken rotor bars for example will cause vibration signatures that are a departure from the baseline signature of the motor in normal operation. As a general rule, the best advantage to be had from vibration analysis is trending vibration patterns.

Alarm levels of vibration are often applied in the field, but in many cases simple alarm levels just don't work. In any motor application, there will be a multitude of variables that affect the levels and frequencies of vibration that occur in normal operation. So a one- time look at the vibration levels of a motor isn't as effective as having a set of data taken over time, and comparing that to the baseline values of the motor.

With the gaps in the capabilities of each of these technologies, what works best is a hybrid approach to motor testing. When EMT is performed and data is revealed that leads to a particular conclusion, vibration analysis can be utilized as an adjunct method to correlate the EMT findings. In mechanical modes of failure, where the magnitude of the fault is insufficient to impact air gap eccentricity enough for a conclusive finding, Vibration analysis could find run speed peak sidebands that confirm the less-than-perfect EMT findings. Conversely, when vibration analysis gives indications that are slight departures to baseline readings, corresponding EMT data can be used to confirm the data. This two-pronged approach can ultimately lead to discovery of failure modes in their infancy, which as we all know is the ultimate aim of a reliability centered maintenance program. Correlation and confirmation are the name of the game, and when you combine testing technologies, the whole is indeed greater than the sum of the parts.

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