CURTISS-WRIGHT

Monitoring Radar Mechanical Drive Systems

FAA's choice of monitoring solutions

Mission-critical

Ask the public to name mission-critical systems, and air traffic control radar will be at the top of the list. The FAA utilizes Airport Surveillance Radar (ASR-9) systems, such as the one shown in Figure 1 at the right, to control incoming and outgoing air traffic at high density US airports and support facilities. The other primary radar for commercial air traffic control is Airport Surface Detection Equipment (ASDE-3) radar, normally installed on top of an airport traffic control tower. ASDE-3 systems manage ground traffic at larger airports across the country and are critical when weather is bad and visibility is poor.

Figure 1. *ASR-9 radar tower*

The Armed Forces also use radar systems, including minimally attended radar sites (formerly known as Distant Early Warning, or DEW, radar) not only for controlling military air traffic but for managing national defense.

\Whether military or commercial, radar systems share two things in common: 1) all are low-speed, rotating machinery; and 2) failures are expensive. In commercial air traffic a single failure can shut down an airport and, like dominoes, start a cascading process of flight delays, cancellations, and rerouting.

Problems with Traditional Condition Monitoring

The FAA attempted to use traditional condition monitoring equipment, which is based on vibration analysis, to monitor the operating condition of its radar systems. The Agency experienced the following problems with this approach.

First, vibration analysis is inaccurate when used on low-speed, rotating equipment. It does not detect problems early enough, and it cannot provide accurate predictions about the timing of a failure on this type of equipment. This is especially problematic for FAA radar systems because they are monitored and maintained by a central group that is remotely located.

The remote location of maintenance personnel, while advantageous from a staffing and expense perspective, creates a lag in response time before a problem can be addressed. Without insight into the severity and timing of a problem, the central staff could not easily and accurately schedule maintenance. If a vibration-based system produced a "false alarm", the result was an unnecessary and expensive response.

Secondly, vibration-based systems produce complex data, which is difficult to interpret without extensive training and specialized skills. Local technicians at the radar sites did not understand the vibration-based data, so they replaced drives when they could "hear" the motor from the ground.

The FAA Finds a Better Way
Fortunately, the FAA found an alternative approach. High frequency sound-based Stress Wave Analysis (SWAN™) techniques do not suffer from the inherent limitations of vibration analysis. Stress Wave Energy (SWE)-based on structureborne sound rather than motion-is an excellent indicator of the overall health of radar mechanical drive systems because it provides direct measurement and comparison of the amount of friction and impact occurring within the equipment.

Regardless of when failures occur during a mechanical drive's life cycle, they start as small discrepancies and progress to larger ones that result in secondary damage, unacceptable operating conditions or catastrophic failure. Traditional diagnostic techniques do not provide a clear indication of problems until late in the failure process, if at all. Stress Wave Energy measurements, however, provide a quantitative measure of friction and shock events during the machine's entire life cycle.

In this application note, we will illustrate how the FAA has utilized SWAN technology to accurately assess the health of radar systems, predict the progression of a problem or failure, and move to a paradigm of true predictive maintenance.

The ASR-9

The ASR-9 requires monitoring for a rotary joint plus two of each of the following: drive motors, clutches, gearboxes, and pinion gears, as shown in Figure 2. A Stress Wave Energy Operating History chart trends stress wave energy over time and is plotted against a backdrop of health-indicating color zones (green/yellow/ red). Figures 3 and 4 show the Stress Wave Operating History from the two motors on an ASR-9 drive, charted over a period of just under 450 hours.

Figure 1. *ASR-9 Drive*

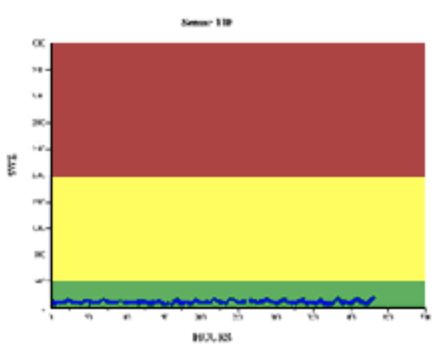

Figure 3. *SWE history from ASR-9 right side motor shows healthy operating condition.*

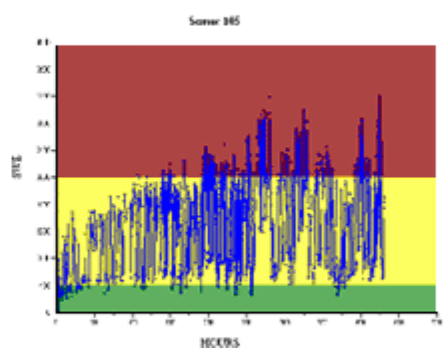

Figure 4. *SWE history from ASR-9 left side motor shows elevated SWE levels with a wide an increasing dispersion.*

In Figure 3, the right side motor shows a low, stable SWE level. A quick glance shows that the machine's condition is clearly in the green zone, trending steady, and it is in healthy operating condition. Figure 4 tells a different story. The left side motor shows elevated Stress Wave Energy, with extremely erratic and upward trending. The SWE levels are in the yellow zone, spiking into red. A quick glance at this chart clearly shows the motor is in distress.

In the case of this radar, the FAA is able to monitor the progression of the fault over time and accurately predict the optimum point at which to schedule repair. Stress Wave Spectral Analysis

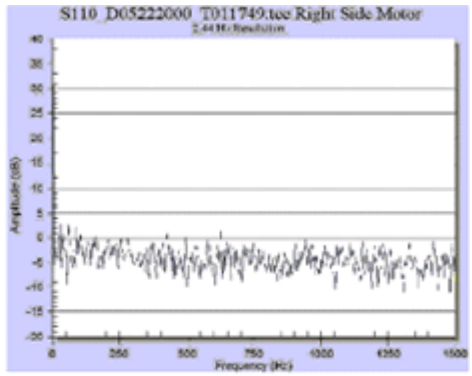

Figure 6 shows Spectral Analysis for the right side motor, with a low noise floor and no significant spectral peaks. Spectral Analysis for the left side motor, shown in Figure 7, has a slightly raised noise floor with significant spectral peaks at 107Hz. The elevated background noise confirms increased friction levels, and the frequency peak at 107Hz is consistent with the fault frequency for the motor bottom bearing. Thus, SWAN technology was able to identify the damaged element without having to first take the unit out of service.

The ASDE-3

The ASDE-3 has a single drive motor, an intermediate shaft, and a main shaft comprising its mechanical drive system. The ASDE-3 was originally designed as an intermittent use radar and is now used 24 hours per day, 7 days per week.

Figure 5 shows the intermediate shaft of an ASDE-3 mechanical drive system. Two SWAN sensors with bolt-on mounts detect stress wave energy from the bearings at the bottom and top of the shaft.

The Stress Wave Operating History charts from the sensors on the intermediate shaft started out in the green zone. However, SWE levels began climbing into the yellow zone about 30 days after installation, indicating an early stage fault. A look at Stress Wave Amplitude Histograms provides additional information on the intermediate shaft's health.

Figure 8 shows three Stress Wave Amplitude Histograms taken from the bottom sensor on the intermediate shaft. The histogram at the top shows a relatively tight bell shaped curve with a MEAN value of .43 peak volts.

The Stress Wave Analysis Histogram in the middle of Figure 8 shows that, 30 days later, the sensor has begun to detect a slight increase in friction. The histogram is still a relatively tight bell-shaped curve; however the mean has shifted from the baseline of .43 peak volts to a new mean value of .94 peak volts.

The histogram at the bottom of Figure 8, taken 60 days after installation, shows that Stress Wave Energy continues in a relatively tight bell-shaped curve. The mean, at .90 peak volts, and standard deviation show that the damage has not progressed beyond what was seen at 30 days. In this case, SWAN tools allow maintenance personnel to keep an eye on the developing fault, but not take the equipment out of service until necessary.

As shown in the above example, SWAN provides the earliest possible detection of a fault. It also shows how the progression of a fault can be tracked over time. Utilizing these tools, the FAA is able to avoid either of two significant problems: 1) taking the radar out of service for maintenance too early, incurring unnecessary expense and downtime; or 2) risking a catastrophic failure and damage to other components.

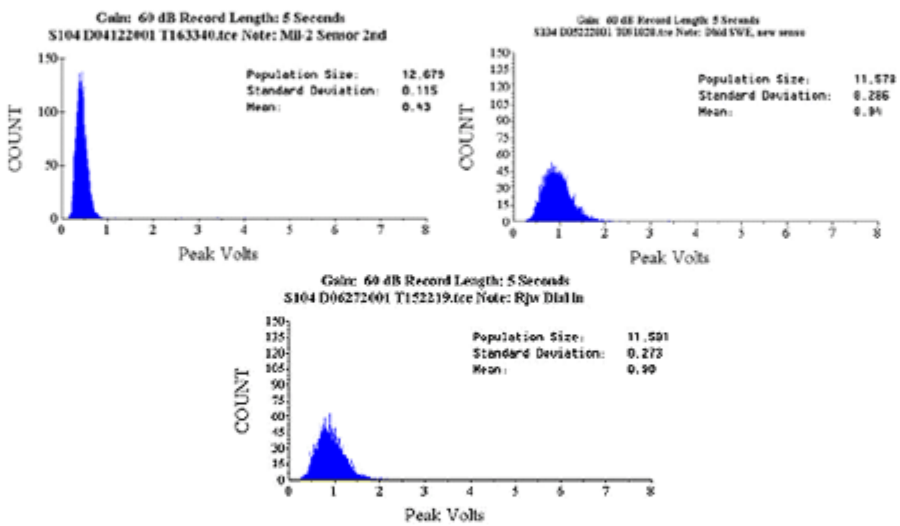

Figure 8. *Stress Wave Amplitude Histograms taken at installation (top), 30 days later (middle), and 60 days later (bottom) show the beginnings of an early stage fault in the intermediate shaft.*

SWAN: When Failure is not an option.

The FAA's experience with SWAN technology for its ASR-9 and ASDE-3 systems has provided insight into operating health that was not previously available. Detecting problems at their earliest occurrence eliminates unscheduled maintenance, allows maintenance to be scheduled at optimal points, eliminates secondary damage, and extends component service life. The result is lower costs, both for labor and parts.

SWAN technology also enables continuous condition monitoring and eliminates false alarms, reducing the number of site visits for mechanical assessments. At least a 500% growth in signal strength is required to reach the red zone threshold. When this occurs, without question an undesirable condition has developed in the mechanical drive system. When it is pulled from service, it will show clear signs of wear or physical damage.

SWAN technology provides timely, accurate assessment of the health of mission-critical operating equipment. SWAN tools accurately detect even slight shock and friction events, bringing low speed rotating equipment like radar mechanical drive systems under the control of true predictive maintenance- for the first time.

Contact Information
Email: stresswave@curtisswright.com
Phone Number: (208) 497-3333