Ultrasonics Plays Key Role in Nuclear Generating Station's PdM Program

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The Palo Verde Nuclear Generating Station uses six emergency diesel generators (Copper Bessemer, 20-cylinder turbocharged "V" engines each rated at 5000 kilowatts) to provide plant emergency power in the event of loss of offsite power. Palo Verde is a three unit site and there are two emergency diesels per unit. Between 1994-1996, the Emergency Diesel Generator (DG) engines at the station had experienced some valve train crosshead/roller failures which were not detectable using standard vibration signals using a typical accelerometer. To address this issue, the DG Maintenance Team added ultrasonic monitoring into our Engine Analysis Program.

The DG Team soon discovered that a properly tuned ultrasonic signal can diagnose subtle valve train problems that may be routinely missed by a standard vibration signal. More importantly, a properly setup ultrasonic signal can provide early warning signs of valve train crosshead/ roller scuffing and galling. If crosshead and roller wear is not been detected early, excessive scuffing and galling may occur and lead to crosshead seizure.

During one of Palo Verde's 1997 refueling outages, a typical crosshead scoring problem in its early stage was uncovered using an ultrasonic signal. The DG Maintenance Engineer noticed an abnormal ultrasonic trace on the intake valve opening event. This early warning sign was not discernible with the standard accelerometer vibration trace. The ultrasonic trace showed spikes with symmetry about the intake opening event. Technicians removed the valve train on the head and found that the crosshead had a rub about the size of a quarter. The DG Maintenance Team cleaned up the crosshead rub marks and returned the engine to service. In a post-maintenance inspection, the ultrasonic trace was back to

Crucial Cylinder Test Points

Figure I shows the location of the vibration and ultrasonic test points on the cylinder head. A technician attaches a standard vibration accelerometer on the lower left cylinder head stud, which is accessed by removing the valve train inspection cover. The other two test points on the cylinder head are taken on the injector with the accelerometer and on the lower center valve cover cap screw using our handheld ultrasonic instrument and its contact probe. Our technician sets the probe with the gain knob at 5.0 and the frequency range knob at 70 kHz. The ultrasonic test point is taken on the center valve cover cap screw because after many months of trial and error, it tends to be centered over the intake and exhaust crosshead/ roller assembly and gives the best signal for crosshead rubs. Problems with crosshead rubs are believed to be caused from marginal lubrication. Palo Verde's engines have had a history of problems with intake and exhaust crossheads and rollers, and some have been found to extremely scored and scuffed. Some have had roller pin failures. In 1994, Palo Verde almost had to shut down a unit because an exhaust cam roller on a 2B engine had worn completely through the hardness layer.

Missed Opportunities

Because of a number of missed opportunities in the 1990's, Palo Verde's maintenance team was eager to try another type of monitoring probe on its emergency diesel engines. At that time, PV diesels had several severely scored intake and exhaust crossheads and two broken crosshead pins that were undetected by the standard accelerometer signals.

Figure 3 shows a set of left bank standard vibration signals taken on the Unit IA Emergency Diesel Generator. The number "six-left" cylinder had an exhaust crosshead roller pin failure, however the roller was still functioning. If you look closely at the number 6-L trace in the figure, there is an anomaly in the signal slightly before the valve closure event which the team thought was due to crosstalk from the number five-L cylinder.

When we used the "marker" view to look at the anomaly, the spikes lined up with combustion noise from five-L so we did not suspect a problem. We also had a similar undetected broken exhaust crosshead roller problem on the other engines. After several of these missed opportunities, we performed a formal root-cause-of-failure investigation, and decided to

Ultrasonics Pinpoints the Problem

Figure 4 shows a typical failed crosshead roller pin (which had broken in the middle similar to another engine's broken roller pin.) Figure 5 shows the signals from the original 9220 ultrasonic probe.

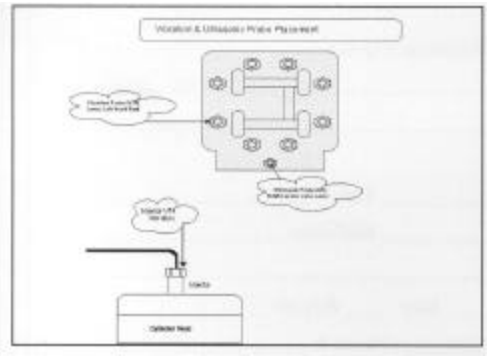

Figure I -The location of the vibration and ultrasonic test points on the cylinder head.

Accelerometer on Head Stud VT4 Set-up

Accelerometer on Injector

Figure 2 - The accelerometer on the lower left head stud with the inspection cover removed, and the accelerometer on the injector nut with the inspection cover in place.

Engine 1-A Sticky Intake Crosshead

Note: No obvious anomalies present in the standard VT4 signal

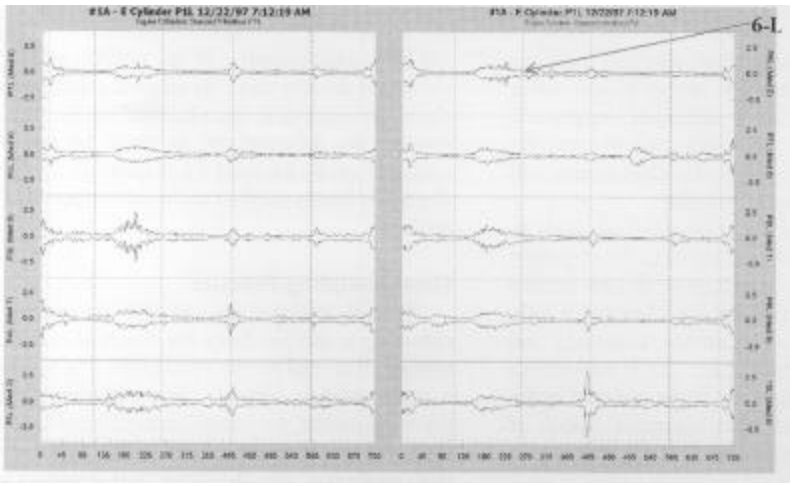

Figure 3 - A set of left bank standard vibration signals from Unit]A Emergency Diesel Generator.

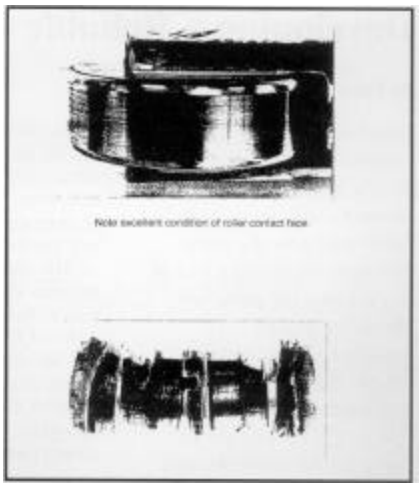

Figure 4 - A typical failed crosshead roller pin.

Clearly, the signal was not tuned for crosshead rubbing. After several engine crosshead missed opportunities, this test point was abandoned. The reason the original ultrasonic system did not produce good signals is because there was not a gain and frequency custom adjustment. Figure 6 shows the ultrasonic trace from the LJE probe using the Recip-trap VT4 setup. An anomaly around the intake valve closing event on the Six-L cylinder revealed itself. During the engine overhaul outage, the head was pulled and the DG Team discovered that an area about the size of a quarter on the crosshead had no clearance and on one spot there was some minor galling. The clearance between the crosshead and its guide was increased back to specification and the galling was removed. The crosshead was reused. In the post-outage engine analysis, the anomaly seen in the before outage ultrasonic trace had disappeared.

How Diagnostic Results Are Reported

Maintenance engineers work directly with maintenance team leaders, each of whom is responsible for a major plant system. The maintenance engineers give recommendations to team leaders via face-to-face meetings (which usually occur several weeks before scheduled diesel outages and just after the diesel generator engine analysis work task has been performed) and followed up with e-mail's. A report is written after each engine analysis based on the collected information which includes pressure, vibration and ultrasonic data.

The reports include a recommendations section categorized as: "must do" for findings that would jeopardize the diesel generator's ability to perforrn its design function; "should do" for the next scheduled diesel maintenance items. The "should do" findings are less important problems which could affect the engine's long-term life/efficiency. Finally, "minor" finds (e.g., anomalies) are noted as "trend only" items for periodic recheck. The reports are included in the engine analysis work order.

The PdM Group also performs vibration analysis, thermography and lube-oil sampling and testing on important plant equipment. The PdM Group has a formal reporting system called Condition Notify Report (CNR) which categories equipment problems similar to the three-stage approach previously described. The only difference is that the CNR uses the terins: "Restricted Operations, Alarm, Alert." The CNR is distributed to system team leaders, maintenance supervisors and plant managers.

The Palo Verde engine analysis program has other achievements, some of which include: better engine balance; development of "rules" for engine adjustment; normalizing data to environmental conditions; and as a monitoring tool that maintenance activities are performed correctly.

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Original Ultrasonic Signal Not Adequate

.Original VT5 probe was too uniform
.No definition in Signal with events

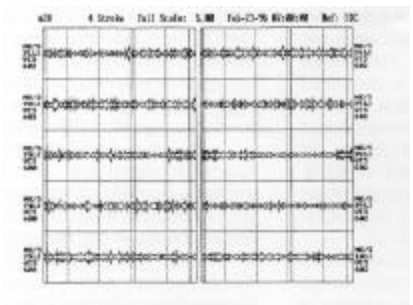

Figure 5 - The signals from the original 9220 ultrasonic probe.

Engine 1-A Sticky Intake Crosshead

Valve Cover - Ultrasonic Signal

symptom

Irregular ultrasonic trace around intake closing event of 6 -L

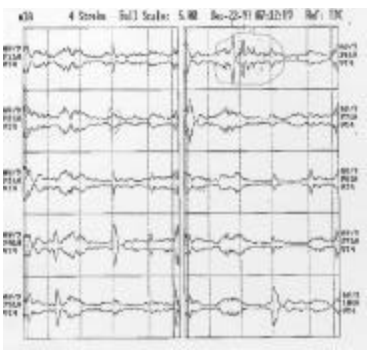

Figure 6 - The ultrasonic trace from the UE probe using the Recip-trap VT4 setup.