Technical Abstract
Advanced discontinuity detection topics for engine valves

Valve Seat Bond Defect Detection

Executive Summary
40 sample valves were evaluated with Resonic acoustic resonance technology for detection of porosity or “open-bonds” in the deposition welded valve seat material. Using existing valve test hardware and signal analysis software, a range of sub-surface flaw sizes was successfully detected in a method very similar to fillet “forge laps” detection.

Equipment Setup and Samples Tested
The equipment setup in this study used a Resonic bench-top valve-scanning unit with two axes of motion and a new valve testing block that was 3D printed with ABS plastic for high precision sensor placement on the fillet (Figure 1). Sensors consisted of a single pair of shear wave EMAT pencil probes. Samples evaluated were 40 diesel engine exhaust valves with 0.375” stem diameter, 1.8” head diameter, and 9.5” overall length. Of the 40 total valves, 10 were suspected to be defect free and 30 were suspected to have “misbonding” defects in the bi-metallic seat weld.

In this test procedure valves were oriented in the typical fillet inspection orientation with sensors directly tangent and orthogonal to the under side of the valve head and in this case the angled valve seat surface. Testing was done with .005 to .010 in. liftoff between sensor faces and the seat face while the valve rotated exactly 1.2 full turns or 430 degrees at 60 RPM.

Data Collection
For each test of a valve seat, approximately 200 time series data points were collected per 1.2 rotations of the part which is equivalent to one data point every 2.14 degrees of rotation. For each data point the ARIS testing software located and logged the peak resonance amplitude from within a frequency window of 1.675 to 1.725 MHz and the sequence of consecutive peak amplitude values makes up a data array which is referred to here as a “valve seat profile”. Figure 2 shows a graphical plot of a full valve seat profile including indications of a bonding defect.

Figure 1. ARIS bench-top valve scanning fixture with 60.5° seat angle sensor block.
Results

Individual seat scan profiles that were observed during testing are generally flat from start to finish except for when the presence of sub-surface, “open-bonds” causes attenuation of peak resonance strength or amplitude “drop outs”. The amplitude plot of a defective valve in Figure 2 shows two “drop-outs” that correspond to a single, large subsurface defect. There are two indications since both sensors pass directly over the top of the defect at different times when they are traveling along the same circumferential path around the valve seat. One indication is a true change in resonance, the other is a “shadow” but is still useful here since it can help to create a redundant detection scheme.

Of 40 valves, 10 were provided to Resonic as known “good” samples. These 10 profiles are plotted in Figure 3. After scanning all 30 of the remaining valves 15 were decided to be “good” and 15 showed indications of misbond.

Figures 4 and 5 show the plotted scan profiles of these two separate groups of valves. To complete the automated detection scheme we would likely want to create an amplitude failure threshold at around -10 which would effectively allow for the rejection of all the suspected defects. We also believe that there are ways to make incremental improvements in signal performance through changes in EMAT specs and refinement of the test setup during the implementation phase. This would help to stabilize the scan profiles of good parts and thus reduce “false positive” errors in a test that assumes all parts are defective until proven to be free of defects.
**Figure 3.** Profiles of 10 defect free valve seats. These valve profiles show some random noise but are all generally flat from start to finish with very few individually identifiable drop-outs.

**Figure 4.** 15 valves from the suspected defective lot do not show major defect indications

**Figure 5.** 15 valves from the suspected defective lot show clear defect indications

**Further Analysis**
Sectioning and polishing of selected valves that were identified as having seat bond defects during the ARIS feasibility testing confirmed the presence of internal defects.