Technical Abstract
Advanced discontinuity detection topics for engine valves

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Engine Valve Combustion Face Defect Detection

Equipment Setup
For this alternative valve head testing procedure we used the same Resonic bench-top valve-scanning unit with two axis motion control. The exact same pair of SH wave EMAT pencil probes were set up on 9 samples of .375 stem diameter diesel engine exhaust valves in order to test for surface defects on the fillet. In this procedure the sensors were positioned on the valve combustion face and did successfully detect the fillet defects measuring resonance through the thickness of the valve head.

The valves were oriented vertically with stems clamped in a 3-jaw lathe chuck in order to provide rotation. Pencil probes were held in a fixture block that oriented them perpendicular to the valve combustion face. A second fixture block constrained the valve stem about 2” below the head to control any run-out while the valve was spinning.

Figures 1 and 2. Test setup used for data collection.

Data Collection Highlights
- .005 to .010” sensor liftoff distance
- 60 RPM valve rotation with 2 full turns of data collection @ 70 data points per turn
- Sensor path of travel on combustion face = .586 in. radius circle (same as fillet test)
- Sensors spaced at approximately 80 degrees
- Nearly identical measurement parameters to fillet approach, indicating that the same resonant modes were generated from the combustion face
- Narrow bandwidth (0.060 MHz) centered around 1.5 MHz
Results
With this test setup we retained the robust ability to detect fillet defects but lost the ability to specifically locate them with scan profiling. The most important signal of a defect in this case was that overall amplitude through the scan was decreased on the cracked parts. Raw resonance signals over the entire valve head of both defective samples (Figures 4 and 5) consistently showed resonance of lower amplitude and quality compared to valves without defects (Figure 3). We consider the signal shapes in Figures 4 and 5 to be a degradation/attenuation of the expected signals on good parts as seen in Figure 3, which has strong and stable peaks.

Figure 3. Typical raw signal snapshot on good parts.

Figure 4. Raw signal snapshot on valve head with smaller crack.

Figure 5. Raw signal snapshot on valve head with larger crack.

Overall the amplitude profiles of scans taken on the face were more stable and flatter than when testing from the fillet as can be seen in the following plot of 9 valve scans. This is likely due to improved part symmetry allowing for more repeatable sensor placement, and more consistent part surface finish.
Figure 6. Peak amplitude plots of 9 scanned valve faces (same ID numbers)

Detection Mechanism
Like before, we can construct a calibration set of good valves and a failure threshold that accounts for all the acceptable amplitude variation in defect-free valves. This time we did not normalize and align the scans because there are no strong defect features. The shaded area in Figure 7 defines a region of acceptable amplitude variation bounded by 2.0 standard deviations on either side of the mean of the 7 good samples, which clearly excludes the scans the defective parts.

Conclusions
Testing conducted with the sensors positioned on the combustion face offers unmistakable identification of the cracked parts, as well as increased signal quality and simplified sensor positioning solutions compared to measurement on the fillet. The two defective parts are easily identified against a sampling of good parts with a large margin for error, due to improvements in measurement consistency and the dramatic impacts of cracks on the resonance of all possible test locations on the valve face.

While the results indicate that detection of the two defective samples might even be easier with the sensors positioned on the valve face than on the fillet, the method of detection may be challenged by smaller defects. On the other hand if these defects are representative of the degree of sensitivity required, this technique is ready for immediate implementation.