January 2002

Estimation of the Measurement Error of the Advanced Digital Ultrasonic Mapping (ADUM) System

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Morrison Scientific was asked by the Integrity Assessment Pipeline Group to plan an experiment to estimate the measurement error of the ADUM system. A matrix of flat-bottomed drill holes was computer numerically machined into a short joint of pipe. The wall thickness of the pipe was about 10.5 mm. The holes are of remaining wall approximately 7 mm (six holes), 4 mm (three holes) and 1 mm (three holes). The diameters of three of the 7 mm remaining wall holes were 5 mm, all the other holes being 10 mm in diameter.

A single Vernier measurement of the penetration of each hole was made at the machine shop where the holes were drilled, the remaining wall being obtained by subtraction. Three measurements of each hole by an independent Level II Certified NDE Technician were obtained using the Pen Probe. Four measurements of each hole were obtained by the ADUM.

The measurement error was estimated using the Case I BMM (Bhatia, Mangat and Morrison (1998)) estimator. This estimator uses repeated measurements (one or more) by each tool to assess the measurement error. The average of the reference tool measurements for each drill hole, given by the Pen Probe and Vernier in this experiment, is treated as the true value of remaining wall for each drill hole. The error associated with the ADUM tool, consisting of the errors due to the Pen Probe, the Vernier, the ADUM and the operators of all three tools, is reflected in the measurement error assessment of the ADUM. The measurement error estimated for the ADUM is therefore higher, by an unknown amount, than the true measurement error of the ADUM.

Using the Pen Probe and Vernier as reference tools, and the ADUM measurements, the estimated measurement error of the ADUM is 0.202 mm. In terms of inches, 0.202 mm is equal to 0.008 inches, so the estimated standard deviation of measurement error is 0.008 inches.

Based on earlier studies with different inspection tools, all other things being equal, we would approximate that a remaining wall measurement error in the 0.202 mm (0.008 inch) range translates into a standard deviation of measurement error for RSTRENG estimates in the range of 200 kPa or 30 psi.

A scatterplot of ADUM reporting of remaining wall vs. the average of Pen Probe and Vernier measurements shows that there appears to be a slight overestimation of remaining wall for shallower features and a slight underestimation of remaining wall for deeper features. The disagreement is due to a combination of reporting by all three tools. Again, the reader should note that the variable bias and measurement errors given here are not solely due to the ADUM, but are due to all three tools and their operators.

In practical terms, the measurement error of the ADUM is very small.

Reference

Bhatia, A., Mangat, N.S. and Morrison, T. (1998). Estimation of measurement errors. *Proceedings of the International Pipeline Conference 1998*, Calgary, Canada, American Society of Mechanical Engineers, Vol. 1, pp. 315-325.