http://dx.doi.org/10.21611/qirt.2006.035

Enhanced Reconstruction of Thermographic Signals for NDT

S.M. Shepard, Y.L. Hou, J.R. Lhota and T. Ahmed
Thermal Wave Imaging, Inc., 845 Livernois, Ferndale, MI 48220 USA
sshepard@thermalwave.com

Since its introduction in 2000, several independent investigations have confirmed the increased sensitivity and depth ranging capability of the Thermographic Signal Reconstruction (TSR) technique. In various studies, it has been applied to data from pulsed, pulse phase and modulated heating experiments, and in each case, the TSR results have outperformed raw or conventional processing results. Recent enhancements to the basic technique have resulted in further performance improvements. In particular, the enhanced TSR technique has optimized to accommodate data from noisy and nonlinear sources, such as uncooled IR cameras. The improvements also allow much higher measurement accuracy, and compensation for flash effects and residual heating. The high repeatability and predictability of TSR processed signals has also facilitated the development of true automated, non-visual processing, and decision-making based on individual pixel behavior in time, rather than image contrast.

With the TSR approach, the time history of each pixel is replaced by a low-order series approximation based on a least-squares fit after an appropriate scaling operation is performed (the particular scaling operation depends on the type of excitation that has been applied to the sample). In pulsed thermography, natural log scaling of both time and temperature result in a monotonically decreasing curve that approximates a straight line with slope –0.5, and deviates gently from linear behavior in the presence of a subsurface feature. A low order polynomial can be used to fit the logarithmic temperature curve to achieve an excellent replica of the original time history, with the added benefit of near-complete elimination of temporal noise and an order of magnitude reduction in the size of the data structure. Close comparison of an original image from the cooling sequence and its TSR replica reveals that the images are nearly identical, with the only difference being high spatial frequency noise that is not discernible to the eye of most observers. In other words, elimination of temporal noise, which seems like a worthy goal, may improve signal-to-noise, but does not necessarily improve the detectability (i.e. target to background contrast) that is most significant for NDT applications. Thus, simple viewing of reconstructed data is unlikely to result in any significant improvement in results for NDT applications.

The true significance of the TSR technique lies in the use of the time derivatives of the reconstructed logarithmic signal. The behavior of the 1st and 2nd derivatives is invariant with respect to variations in input energy, emissivity or typical gradients in excitation energy. Timing of the derivatives may be used to measure thermophysical properties, and the shape of the curves allows one to determine whether a point on the sample surface represents an intact or defective subsurface without referring to adjacent points (in fact, no image is required at all).