Efficient reconstruction of corrosion profiles by infrared thermography

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Abstract

Pulsed Infrared Thermography becomes practical in detecting hidden corrosion in those cases where induced temperature signals are high enough, even if they exist for short periods of time. The principle of operation is based on analyzing spatial-temporal phenomena which occur in corroded sites subjected to stimulated heat diffusion.

The 1D approach assumes that transient thermal events occur independently in sound and defect areas, therefore, defects are to be very large so that the boundary heat diffusion effect can be neglected in the defect center. In such a case an analytical approach is possible. It has been shown [2] that the relative material loss (i.e. the ratio between the residual thickness in the corroded spot and the thickness of the defect-free area) is a function of the temperatures over the defect and the sound area.

When dealing with *small defects*, the lateral heat diffusion is no longer negligible and must be taken into account (2D and 3D cases). In this talk we consider a Finite Element model embedded in a parameter estimation procedure to solve the inverse heat transfer problem. In the numerical model, the corrosion profile is approximated by a function T_θ, piecewise constant, with subdivision step h_θ. We consider particularly situations in which the corrosion profile may have high gradients, as it happens e.g. in problems where there is a localized deep corrosion. It is important to be able to estimate the local depth

of the corrosion. It turns out that to represent the corrosion profile accurately by a piecewise-constant approximation it is necessary to use an h_θ quite small, at least locally. Without substantial limitations in the approach, we will consider a 2D model problem. Indeed, in presence of an heating source of radius $R >> h_\theta$, the response due to the corrosion at a subinterval of T_θ tends to overlap with neighboring responses The ill-conditioning of the estimation problem grows when h_θ diminishes, and becomes critical for the profiles here considered. In this case, it is not possible to leave out some parameters from the estimation process, since there is no a-priori distinction upon their relative importance. Nor it is surely convenient to add a regularization term in the problem formulation, since the only possible a-priori estimates for the parameters value is zero. Instead, we propose to embed a principal component analysis in the estimation algorithm.

A second issue arise because a small uniform h_θ corresponds to a large number N_θ of subintervals and, therefore, of parameters for the estimation problem. This fact brings at prohibitive computing times for a real-time diagnostic instrument, especially in a 3D problem setting. We propose an adaptive subdivison of the profile, based on indicators obtained after iterative comparisons between the experimental measurements and model predictions, i.e. *a-posteriori*. Such indicators can be obtained from the residuals given by the Kalman Filter. This is often used in statistical *fault detection* algorithms precisely for this purpose [1]. The distributed nature of the parameters and of the state-variables in the reference FEM model used in the Kalman Filter make it possible to locally subdivide T_θ according to the indicators.

We show some results obtained from laboratory experiments with metal samples.

References

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[2] V. Vavilov, E. Grinzato, P.G. Bison, S. Marinetti, and M.J. Bales. Surface transient temperature inversion for hidden corrosion characterisation:

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