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A new technique to reconstruct the defect shape from Lockin thermography phase images

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Lockin thermography - thermal tomography - quantitative evaluation - composite aircraft material - non-destructive Testing

In this paper we present a new method for reconstructing the shape of defects in three dimensions from Optical Lockin thermography phase images with images processing algorithms. In [1], a similar method was presented where the reconstruction ("thermal tomography") was performed from pulse thermography sequence.

Lockin thermography is a well known depth resolved method. Thereby, the light excitation is sinusoidally modulated and amplitude and phase images are computed from the time sequence with Fourier transformation. By varying the excitation frequency, it is possible to detect defects in different depth because the thermal depth penetration depends on the frequency of the sinus (figure 1):

$$\mu = \sqrt{\frac{\alpha}{\pi \cdot f}} \quad (1)$$

This property is used to retrieve the defect depth. Therefore, a method based on the local SNR (Signal-to-Noise Ratio) is used to determine the blind frequency. The blind frequency is defined as the frequency at which the defect disappears when the frequency diminishes and a phase reversion occurs. By knowing the thermal conductivity of the material, it is possible to retrieve the depth of defects (figure2).

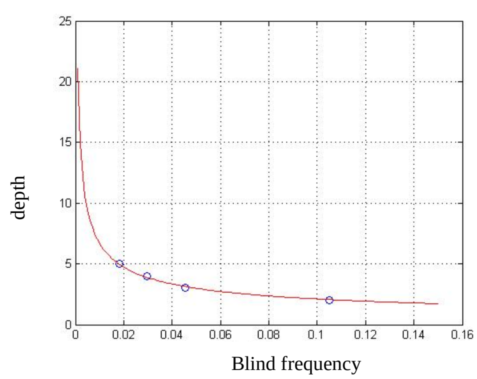

Figure 1: relation between the defect depth and the blind frequency.

In order to perform quantitative evaluation of the defects, a scale has to be introduced in the images in order to get the pixel size. For this, labels are stitched on the pieces

and automatically recognised. The scale is introduced using photogrammetric methods.
The thermal diffusion process influences the apparent shape of the defects. The defects appear greater as they are. This process can be modelled by an inverse problem. The theory of Mandelis [2] of periodic thermal wave fields is used to compute the point-spread function (PSF) directly in the Fourier domain. For these, the problem is modelled by an infinite plate and the born approximation is used. The images are deconvoluted with the PSF in order to get the right defect shape and size.
After a theoretical description of the applied methods, we show measurements on parts and the results of the algorithms.

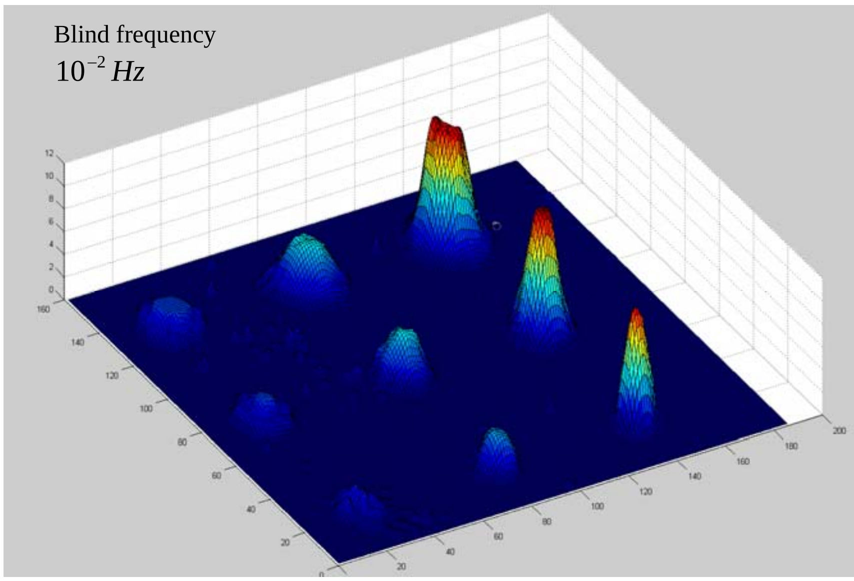

Figure2: Reconstruction of the defect shape of a part with drilled holes.

References:

[1] Vavilov, V.; Maldague, X.; Picard, J.; Thomas, R.L. & Favro, L.D.,
Dynamic thermal tomography - New NDE technique to reconstruct inner solids structure using multiple IR image processing (Plenum Press, New York)
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[2] Mandelis, A.
Diffusion-Wave Fields-Mathematical Methods and Green Functions, Springer (ed.) 2001