**PULSED PHASE THERMOGRAPHIC DEFECTS DETECTION BY SCANNING THERMOVISION CAMERA**

Kopal I., Koštial P., Hutyr J., Mokryšová M., Rusnáková S.

Institute of Material and Technological Research, Department of Physical Engineering of Materials, Faculty of Industrial Technologies, University of Trenčín, T. Vansovej 1054/45, 020 32 Púchov, Slovak Republic, kostial@fpt.tnuni.sk, www.fpt.tnuni.sk

**Introduction.** The active infrared thermography with external thermal stimulation was established as a fast and reliable tool in many areas of nondestructive testing. Numerous experiments have demonstrated that especially the pulsed phase infrared thermography method is very effective for contactless testing in several industry branches. It is a promising technique for rapid large area inspection for a variety of defects, such as voids, inclusions, delaminations, porosity, impact damages or cracks. A new generation of infrared cameras with focal plane array detectors provides a higher spatial resolution and improved defects sensitivity, as compared to the scanning thermovision cameras. However, a meaningful software treatment of the original thermal images before their following image processing by powerful personal computers makes the thermographic inspection via this type of infrared imagers very competitive and often the cheapest method for contactless inspecting of materials, structures and products.

**Materials and Methods.**

The application of pulsed thermographic inspection generally consists of examining the temporal response of observed structure to an external thermal excitation. In the pulsed phase mode of the infrared thermographic investigation a discrete Fourier transform (DFT) of the original digital thermal signal, acquired by an infrared imager, is realized to analyze the experimental temporal data series in a frequency domain.

In a general way, the Fourier analysis provides a more exact data processing technique, that is high sensitive to the various types of subsurface flaws, as well as it offers a possibility for a quantitative investigation of the wide range of materials. The computed phasegrams are very excellent particularly for hidden defects visualization due to their low sensitivity to non-uniform stimulation heating, parasitic reflection of surrounding background, as well as to other kinds of thermal signal distortions [1]. On the other hand, DFT is oftentimes unavailing within the thermal data series obtained by the infrared scanned detector cameras first of all because of their low acquisition rate which effects a low resolution in the Fourier frequency domain [2].

The aim of the described research is to develop such algorithm which would by able to optimize the raw experimental thermal data for the following effectual application of DFT.

**Experimental Procedure.**

The experimental data set has been completed from a GRP/PVC made, sandwich structure panel of 0,025 m thick [3, 4]. A 0,01 x 0,01 m air bubble, located below the panel surface approximately in the two thirds of its depth, was especially created during the process of the specimen production to simulate a void and a bulge inside a real industrial product (Figure 1).

![Figure 1](image)

The external thermal stimulation of the inspected panel surface was realised by a 750 W commercial halogen lamp in a distance of 0,4 m. The following cooling stage was monitored from distance of 0,4 m via the infrared scanned detector camera V-20ER005-25 equipped with one thermoelectrically cooled photo-voltaic HgCdTe (CMT - Cadmium Mercury Telluride) quantum detector PDI-3TE-5 sensitive in a short wave band (3-5 µm). A full time series of the recorded successive digital 240 x 240 truecolor thermograms with a 24 bit resolution was...
transferred via a high-speed USB 2 port into a personal 1.6 GHz / 1 GB RAM computer, than converted into an intensity thermal images set of a numerical class double and arranged into a 3D matrix for an efficiency image processing by a specialized Matlab R14 based software package.

Results.

Within the limits of the available experimental set, the experimental thermal data could be captured nothing but at the sampling frequency of 67.57 mHz per pixel. The cooling down process, after 120s heating of the inspected surface, was observed from the same side of the specimen with a time step of 14.8s. A total number of 64 thermograms was recorded during an observation time of 947.2s. Therefore, the frequency resolution could amount barely to 1.06 mHz and the maximum frequency only to 33.79 mHz. However, the available hardware allowed a notable increase of all experimental parameters via the software treatment of the raw data series.

The 64 points experimental time history of each pixel, extracted from 3D matrix and arranged into the 2D matrix as a multichannel discrete thermal signal, was upsamped to a 512 data points series at 67.57 mHz sampling frequency by application a lowpass polyphase filter to the input sequencies to prevent aliasing during the resampling procedure [5]. The applied linear finite impulse response (FIR) digital filter was designed by using a least-square minimization method with the Kaiser window [6]. Subsequently, the sampling rate of each extrapolated, filtered pixel’s time history was artificially increased ten-fold, by using a cubic spline interpolation technique [7]. Thus by a combination of extrapolation and interpolation with digital filtering of the original temporal thermal signal, processed data set provides a much better starting point for the frequency analysis by the FFT algorithm [8] in comparison to the original data set produced by the scanning thermovision camera [9].

The available hardware allowed the 512 point FFT of the 7577.6s long time domain which made frequency domain with the frequency range of 0-337.85 mHz and the frequency resolution of 0.13 mHz. These parameters returned very restful results. The phasegram presented in Figure 2 reveals both, the well visible subsurface void with the sharp depicted edges and a little bulge located approximately in the one quarter from its right margin.

Conclusions and discussion.

This work is aimed at subsurface defects detection by the pulsed phase thermography on GRP with 2 layers of glass mats made laminate, used mainly in automotive applications. The cooling-down process of each pixel of the observed specimen surface after heating-up with the external heat pulse was analysed to detect voids inside and below the surface.

It was demonstrated that the experimental thermal data series, acquired during the thermographic experiment realized in reflection regime of pulsed mode of infrared thermography by scanning thermovision camera, can be effectively enhanced via the software treatment. The combination of extrapolation and interpolation with the linear digital FIR filtering of the raw temporal thermal signal enables to expand the frequency domain range of DFT, as well as to essentially increase its frequency resolution. Thus, the attained results make possible to obtain the relatively high quality phasegrams with the adequate hidden defects visibility.

References