Data Fusion of Lockin-Thermography Phase Images

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Abstract

Thermography techniques become increasingly important as valuable tools in non-destructive testing of materials. The samples to be tested can be excited by light, ultrasound, induction, warm air, or microwaves and the local thermal response is measured. In combination with powerful analysis techniques, robust images can be obtained.

In our institute we use several of these techniques, but modulated excitation with halogen lamps and subsequent lockin analysis of the data (“Lockin-Thermography”) has proven particularly efficient and robust. This method named Optically excited Lockin Thermography (OLT) is being used in many institutes and companies. It provides phase images that are robust against artefacts like inhomogeneous excitation and variations of emission coefficients over the surface of the sample.

This paper describes a way of correlating two phase images with each other. Figure 1 shows two lockin measurements of a wedge-shaped polymer sample on a wood desk. The thin end of the wedge is on the left. The modulation frequency in the left image is twice the frequency in the right image (0.1 Hz compared to 0.05 Hz). Lockin measurements at lower modulation frequencies show larger thermal diffusion lengths. Consequently, the white area, which indicates a relatively thin area, expands further in the low-freuqency image.

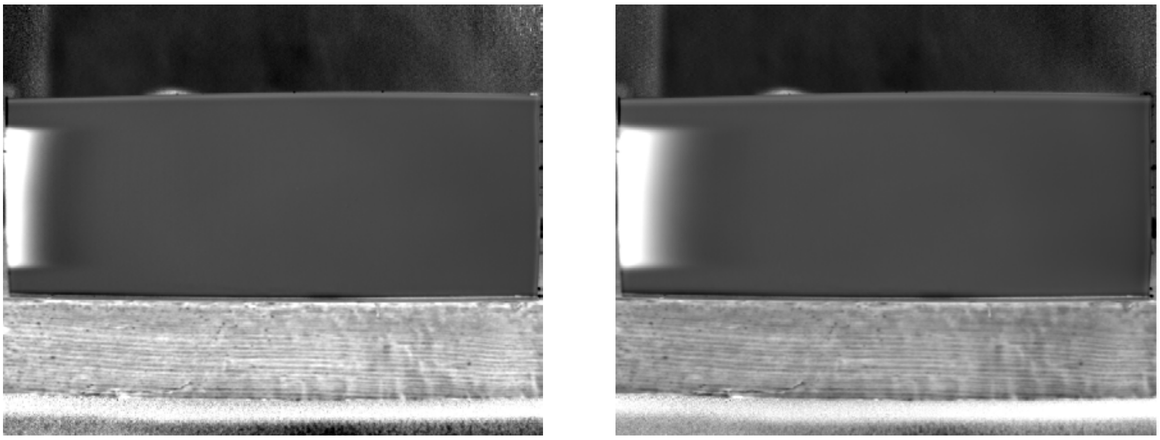

Fig. 1. *Optically excited thermography. Phase images of a wedge-shaped polymer specimen at 0.1 Hz (left) and 0.05 Hz (right).*

Seemingly the two phase angle images taken at different modulation frequencies differ only very slightly from each other. However, both pictures together contain additional information. This hidden information becomes accessible when the phase values for each pixel of the two images are plotted against each other. The infrared camera used has 640 x 512 pixels, so such a plot contains about 330,000 data points. Figure 2 shows the plot which correlates the phase angle value at a certain pixel in the the first image to the one of the corresponding pixel in the second image. This way a cloud of data points is obtained when all pixels are evaluated. Obviously this approach can be applied to n phase images resulting in clouds in a n-dimensional data space.

Figure 2 is such a plot correlating the pixels of the two images in figure 1. Each data point in this complex structure can be traced back to the original image. The “island” in the center of the image corresponds to the wood structure of the table underneath the specimen. The long curved line spanning from the lower left to the upper right is the wedge-shaped sample which can be clearly distinguished from all other pixels.

In theory, when lateral heat flows are neglected, all pixels should be located on this curve. Data points outside this line are related to areas of lateral heat flow or defects which can be visualised this way if other data are suppressed e.g. by applying mathematical procedures that act like spatial filtering in this correlation-plane combining phase data from two images. The more phase images are used the more precise the method becomes so that even mapping of lateral heat flows in different depths becomes feasible after suitable filtering in such a multidimensional correlation space. Additionally, the method can facilitate image processing because certain areas (e.g. the wood table underneath the wedge) can be easily distinguished from important parts of the image.

The paper explains the method, shows mapping of lateral heat flows, and discusses potential impacts on image processing including automatical failure analysis.

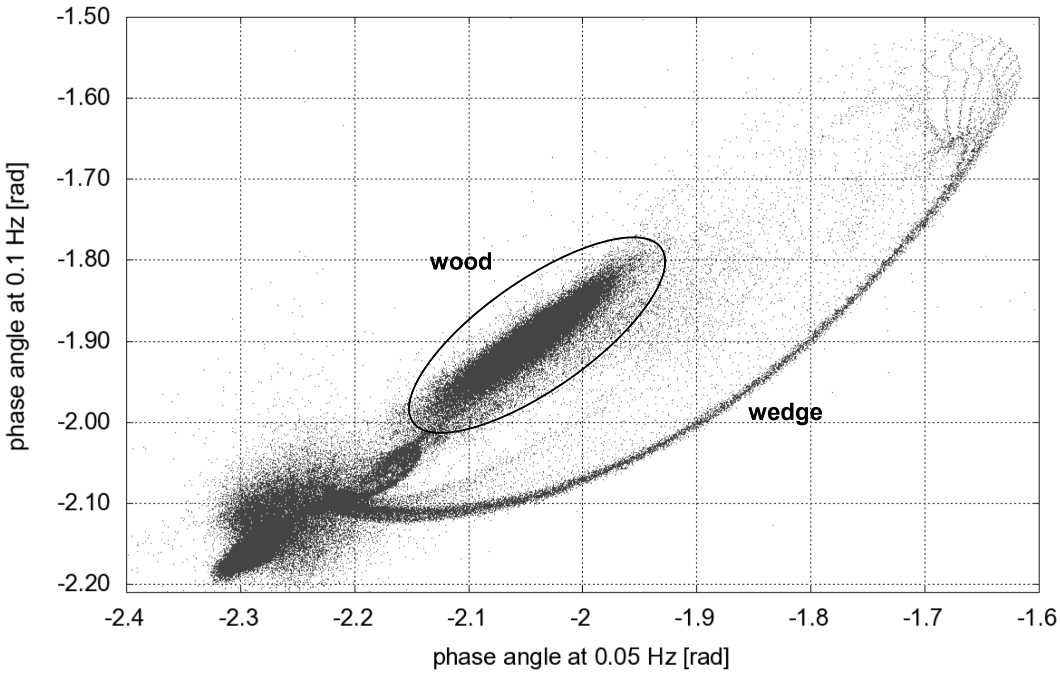

Fig. 2. *Phase values of the images shown in fig. 1 plotted against each other.*