Time-dependent evaluation of inductive pulse heating measurements

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Thermo-inductive investigation can be well used for the detection of surface cracks in metallic materials. In this technique the work-piece is heated by induced eddy currents and an infrared camera is recording the temperature distribution of the surface. Irregularities and failures in the surface cause anomalies in the temperature distribution. Therefore, cracks become visible in the infrared images.

Earlier investigations have shown that in the case of magnetic materials after a short heating period higher temperatures occur around a surface crack. This means, that the failure is selectively heated by the eddy currents. After switching off the inductive heating, the heat transport continues in order to compensate the temperature differences. Because of the higher temperature locally around the surface crack, the temperature decays in this area quicker than in the ranges without any failure. In order to evaluate the decay time-constant for each point of the infrared image, one can use different mathematical techniques, as e.g. Fourier transformation. Technically, the calculation is similar to the often used PPT or burst-phase thermography. But in the case of PPT, thermal waves are reflected from failures inside the material and therefore the calculated phase of the wave gives information about the failure-depth. In the case of selective heating of cracks the Fourier transformation delivers different phase values for different decay time constants. Additionally, inhomogeneous emissivity values and surface effects diminish through the Fourier transformation. Figure 1 shows a sample, which surface has been partially grinded. Because of the very different emissivity of the sample and the high reflectivity of the grinded part, the evaluation of the thermographic measurement based only on the temperature values is not possible. After evaluating the infrared time-sequence with Fourier transformation, the surface crack becomes very well visible at the grinded part (see Figure 2).

In earlier publications models have been presented to calculate the eddy current and the temperature distribution around surface cracks. Based on these models, the phase, resulting from the Fourier transformation of the inductive pulse heating, is now analysed and compared for different situations. Figure 3 shows the phase distribution around surface cracks with different depth values. Figure 4 shows the phase difference between the phases at the position of the crack and at a position far away from the failure, depending on the crack depth. These results show that already a shallow crack a well visible phase difference causes.

In the case of non-magnetic materials the inductive heating result in lower temperature values around the surface cracks. It has been shown, that the eddy current with relatively high penetration depth is pushed from the surface more inside the material, causing colder regions around the cracks. After switching off the inductive heating, the heat is transported in this colder area and the temperature increases also after switching off the heating. Figure 5 shows some timing graphs demonstrating this process: at point ’1’ and ‘2’, located at the crack, the maximum of the temperature is achieved after switching off the heating. Points ‘3’ and ‘4’ are located at the failure-free surface of the wire and have their maximum temperature at the time point, when the heating is switched off. Using Fourier transformation for non-magnetic materials, the calculated phases show a lower value around the cracks and making the failures well visible (see Figure 6). Further investigations have been done, how this phase difference depends on the crack depth and on the material parameters.

***Figure 1**: Steel work-piece with partially grinded surface.*

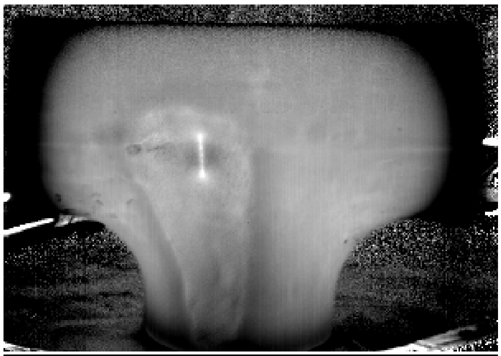

***Figure 2**: Phase image of the work-piece shown in Figure 1, the crack is very well visible at the grinded part.*

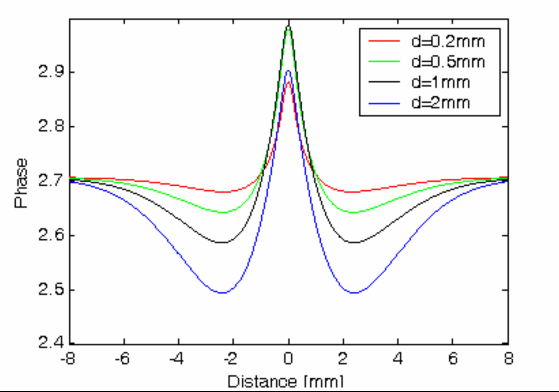

***Figure 3:** Calculated phases around surface cracks with different depth values at the position of '0'.*

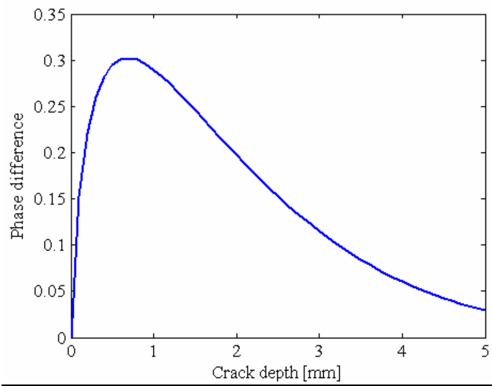

***Figure 4:** Additional phase around a surface crack depending on its depth.*

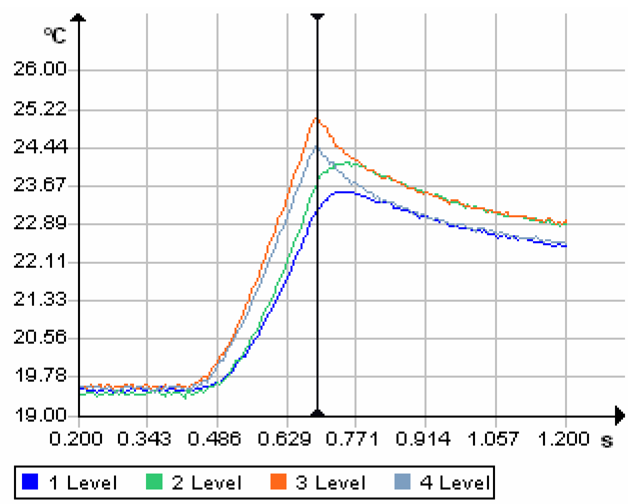

***Figure5:** Timing graphs for inductive pulse heating at some points of a non-magnetic material. Level'1' and '2' are located in the region of a surface crack, '3' and '4' are at the surface without failure.*

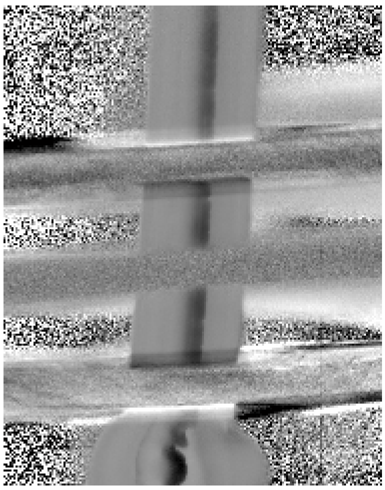

***Figure 6:** Phase image of a non-magnetic wire. The surface crack (cold lap) becomes very well visible through a lower phase value.*