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Probability of detection for short surface cracks using inductive thermography

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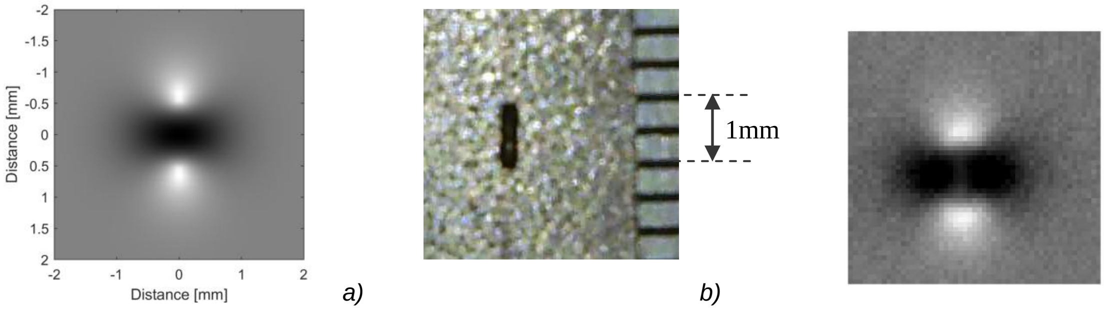
Abstract

Inductive thermography is a non-destructive testing method, which can be excellently applied to detect surface cracks in metals. The work-piece is heated with a short inductive heating pulse of 50-100ms duration and an infrared camera records during and after the heating pulse the temperature. In order to increase the signal and to reduce the noise, the film sequence is evaluated by Fourier transformation to a phase image.

The probability of detection (POD) gives a good measure for the technique's reliability for industrial applications. In the current study the POD for short cracks in nickel-based austenitic superalloys is investigated, using samples with artificial cracks manufactured using EDM technique. On the other hand, the measurement results are compared to finite element simulations. Fig.1a shows the phase image of a simulated surface crack with 1.1mm length and 1mm depth and Fig.1c the measured result for such an artificial crack. In Fig.1b the microscopic image of this crack is depicted.



c)

Fig.1 *Phase image of a FEM simulation (a) and measurement(c) result for a crack with 1.1mm length and 1mm depth; Fig.1b shows the microscopic image of the artificial crack.*

The measurements and the simulations were carried out with an excitation frequency of 60kHz, which causes an eddy current penetration depth of 2.46mm in the superalloy. Around the crack line a lower temperature increase and hot spots at the crack tips can be observed. In a previous work [1], it has been shown that the phase contrast, calculated from the phase maximum at the crack tip and from the phase minimum at the crack side, depends on several parameters as e.g. crack length, crack depth, inclination angle, crack profile etc. Fig. 2 compares the simulated and measured phase contrast for cracks with 0.5 mm and 1 mm depth, depending on the crack length in the range of 0.3 – 1.9 mm.

For the POD calculation the signal-to-noise ratio (SNR) of the phase contrast is used. As noise of the experiments the standard deviation of the phase in the sound, defect-free region of the sample is taken. To the simulation results a noise with normal distribution is added, which has the same standard deviation as in the experimental results observed. This approach does not include simulations of signal response variations due to statistical properties of defect characteristics. To understand the influence of defect characteristics the POD is evaluated separately under different conditions.

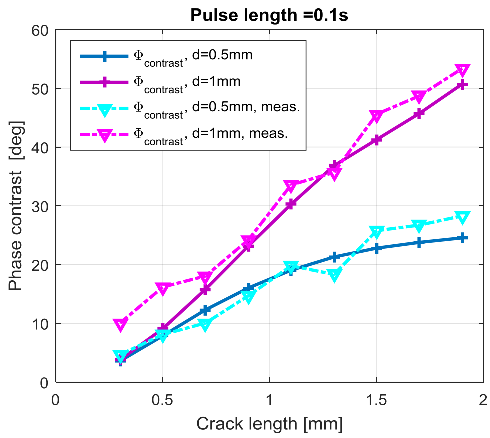


Fig.2 *Comparing phase contrast for simulated and measured results depending on the crack length for two different crack depths of 0.5 and 1 mm*

Fig.3a shows the simulated data with additional noise (blue '+') together with the measured values for the artificial cracks (red 'o'). For the POD calculation the next step is to fit a straight line to these points, and determine the 95% confidence and 95% prediction bounds [2]. Furthermore, the POD curves can be calculated and determine the critical sizes as a_{50} (crack length having 50% POD), a_{90} (crack length having 90% POD) and $a_{90/95}$ (crack length having 90% POD with 95% confidence). The shallower the crack, the less phase contrast occurs around it, therefore the critical sizes for the shallower cracks with 0.5 mm depth are larger than for the deeper cracks with 1 mm depth, see in Fig.3b.

In this study it is investigated how different parameters of the crack geometry and the parameters of the experimental setup the POD of the defects affect.

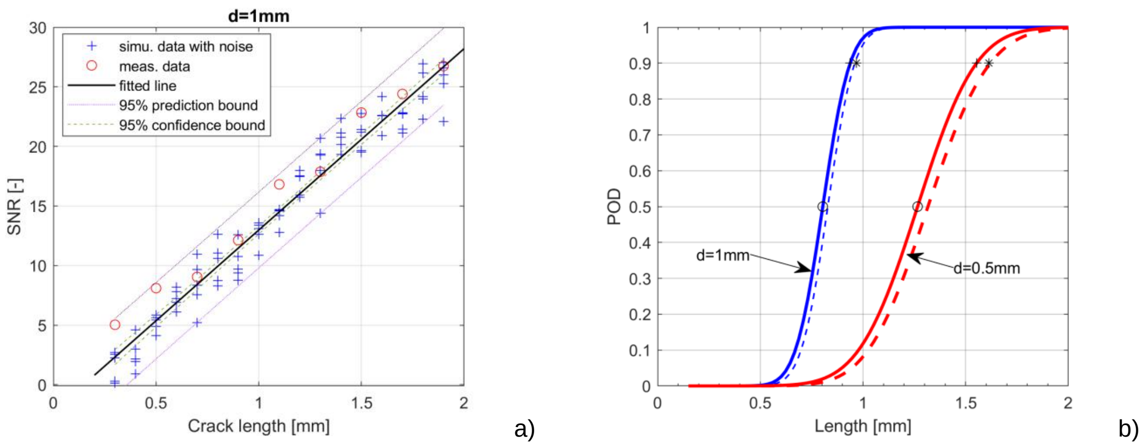


Fig.3. *a: SNR of simulated data with additional noise and measured data; b: POD curves 1mm and 0.5mm deep cracks, for d=1mm a_{50}=0.8mm, a_{90}=0.93mm, $a_{90/95}$=0.97mm; for d=0.5mm a_{50}=1.27mm, a_{90}=1.55mm, $a_{90/95}$=1.6mm.*

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