The influence of surface coatings on the differences between numerical and experimental results for samples subjected to pulse thermography examination

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Abstract

This paper presents the analysis of the influence that black surface paint layers have on the differences in the results obtained from numerical modelling and those obtained experimentally. Surface paints are commonly used for the purposes of pulse experiments in order to increase the sample surface emissivity and help enhance the signal obtained. The paper argues that it is important to include these paint layers in the numerical analysis either directly, as additional material layer, or alternatively, to estimate their influence and take it into account when comparing the corresponding results.

1. Introduction

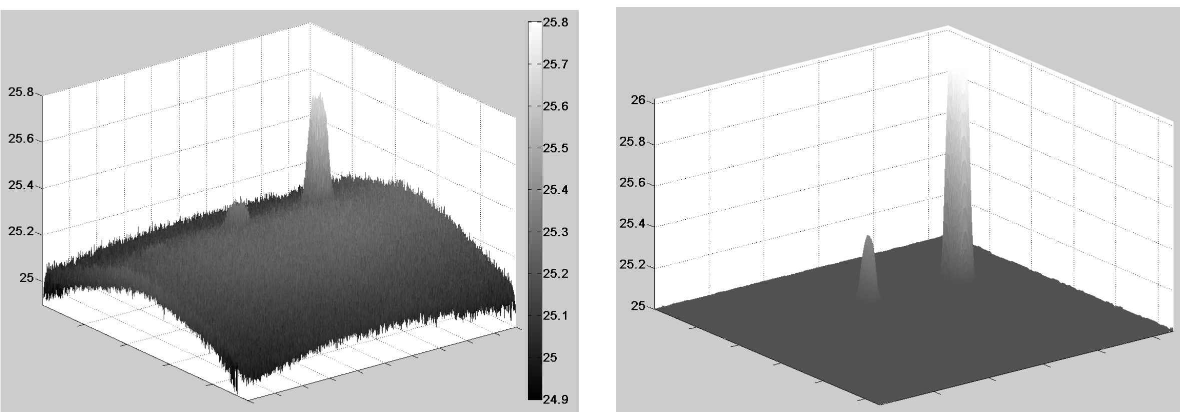
In most cases surface characteristics of materials that are subjected to pulse thermography (or other IR thermography) testing procedures, have poor surface emissivity properties. Since thermal signals have relatively low values of signal to noise ratio (SNR), especially when the temperatures obtained are not much higher with respect to room temperature, different strategies of signal enhancement are commonly used [1]. High emissivity surface paints (ε>0.95) are applied on tested sample surfaces prior to experiments in order to increase the signal emitted and captured by IR camera. These layers of paint are often neglected when thermal contrast analysis is made, assuming therefore that their influence on the experimental results is negligible. However, this article demonstrates that when results obtained experimentally are compared to those obtained from numerical modelling that does not take into account the paint layers mentioned above, the behaviour of the resulting surface temperature decay curves results in differences of maximum thermal contrast as well as the time of appearance.

2. Experiment and model sample description

A flat-bottom hole sample made of Plexiglas with 6 holes all of the same diameter and located at different depths was used in the experiment. The plate surface that was to be exposed to flash heating was painted with black paint of high emissivity (ε>0.96). The experiment was conducted in the reflection mode. At the same time, a numerical model of the sample plate was developed and simulations of pulse experiments were conducted. Two different cases were assumed. In the first model no paint layer was included, whereas the second model had a 25 μm thick surface paint layer. Since neither the precise thickness nor the exact thermal properties of the paint were known, the thickness assumed was the average thickness of such paint layers as reported in the literature, while three different simulations were made in order to obtain the results for three paints of different thermal properties, as specified in [2].

3. Main results and discussion

Figures 1a and 1b show the surface temperature distributions of the Plexiglas plate 10 seconds after the strong heat pulse of very short duration has been applied. Figure 1a) represents the experimentally obtained thermogram while the Figure 1b) is a corresponding surface temperature solution obtained numerically from a model that had no surface paint included.



a) b)

Fig. 1. *Flat-bottom hole Plexiglas surface temperature distribution 10 seconds after heat pulse application a) experimental results and b) results of numerical model without surface paint layer*

Both temperature scales are adjusted to show the same temperature range order to enable the easy colour correspondence comparison. Despite the apparent non-uniform heating effects, it can be seen that while temperatures of the sane area correspond relatively well, the defective area temperatures show differences.

In order to show the importance of the surface paint layer, Figure 2 shows the surface temperature decay curves for both cases: first where no surface paint layer was included and the second when a 25 μm thick black paint layer was included in the model. In the case of the shallowest defect, the difference is significant and, as shown in Figure 3, this can also be seen on the thermal contrast that is reduced to about 82% of the contrast obtained without the paint layer.

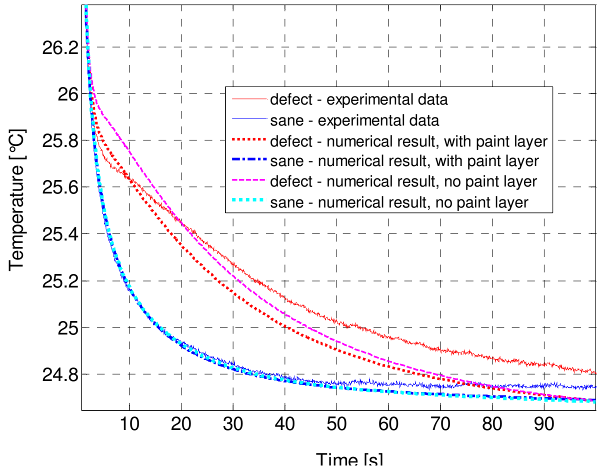


Fig. 2. *Surface temperature decay curves: experimental and numerical results for cases with and without a 25 μm thick black paint layer included in the model*

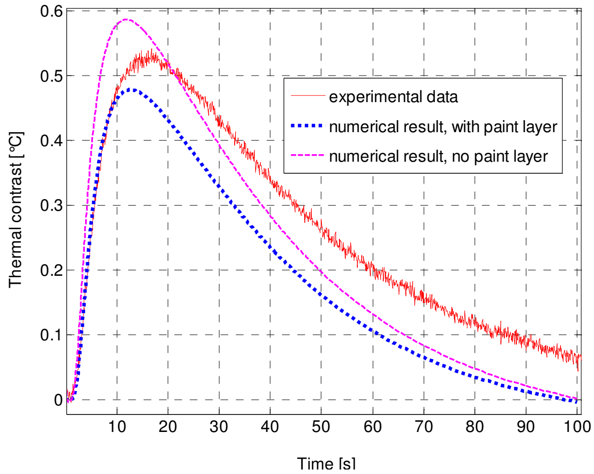


Fig. 3. *Thermal contrast: experimental and numerical results for cases with and without a 25 μm thick black paint layer included in the model*

In addition, the results of the simulations performed with three surface paints of different thermal properties and of the same thickness were found interesting. For all three cases, no significant difference in results was noticed, implying, thus, that the paint layer is too thin for its thermal properties to play a significant role, but its existence as additional layer, in fact, is noticeable since it increases the depth at which defect is located (and therefore affects the maximum thermal contrast obtained).

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