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Microscopic lens thermography for the observation of features in light cardboard

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ABSTRACT

This is a preliminary study for microscopic lens thermography observations on a film-like and non-blackbody material. With this aim, a number of features present on the surface of a cardboard for storage boxes (grammage 300 g/m²) are observed using a Flir SC 3000 thermal imager microscopic lens with 26 mm fixed focal distance. Comments on quality of observation and on probability of false indications depending on on the depth of the features observed are supplied, in particular concentrating on transient time for observation during cooling following illumination and on thermal gradients measured.

Keywords: IR thermography, microfocus, cardboard, probability of detection

1. Introduction

The recent availability of microscopic lens thermography has considerably extended the field of application of this technique, which was originally aimed more at the detection of defects, such as delaminations in composites, with maximal dimensions exceeding a few millimetres. This implies that the technique can be used more as a microscopical method, therefore allowing individuating surface defects or features which are not revealed by a visual inspection. With respect to optical microscopy, IR thermography would be ideally able to offer some information on the gravity of the defect, e.g. by the measured temperature difference with respect to the background, assumed as “normal” or “undamaged”.
Some preliminary studies have confirmed the potential of the application of this technique to very thin, possibly film-like materials. Examples of these studies allowed e.g., the investigation of leakage sites in integrated circuit boards [1] and the measurement of porosities in balsa wood [2], in both cases arriving to spatial accuracies lower than the millimetre. However, some limitation in having a surface response in that range are evident. A first difficulty lies in the fact that what is really obtained and represented in the dynamical thermal map is the global response of the emission from the material in the infrared wavelength range. Less obvious is relating the above response to the presence of defects or abnormal features in the structure. In this regard, the principal issue, where infrared measurements are concerned, is the dependance of emissivity on temperature, wavelength and surface condition [3]. This may conceal the appearance of defects or reduce the time frame available for thermographic observation.

In this study, a number of features present on the surface of a cardboard layer for storage boxes are observed, using a microscopic lens thermographic camera, as a preliminary for a study on a film-like and non-blackbody material. The quality of observation is dealt with and the possibility for false indications in dependance on the depth of the features is also discussed.

2. Experimental

The material under observation was cardboard for boxes (grammage 300 g/m²), with thickness 0.35

mm, polished and of uniform grey 10% colour (RGB scale 239, CMYK 21-0-22-65, HSV 117-22-35) with emissivity around 0.90 in the infrared. The samples were heated up for a 3 seconds period, as suggested by a number of studies on poorly conductive materials, such as fibreglass (e.g., [4]), using a 100 W tungsten lamp, placed at 150 mm from the sample surface. Immediately after the heating period, the samples have been observed using a Flir SC 3000 thermal imager microscopic lens with 26 mm fixed focal distance. In this way, the area under observation was equal to a 10 mm square with pixel resolution approximately equal to 25 microns. Ten images per second have been acquired during the transient time.

3. Results

The material presented no obvious damaged areas: a number of features have been observed by the IR thermography imager, with the idea of providing information about those characteristics, which are more easily observable in poorly conducting film-like materials, such as cardboard. In particular, the features were visualised to measure the level of resolution that could be achieved in this kind of application. The four features observed and their characteristics are listed in Table 1: it can be observed that the transient time in which the features were observable, defined as presenting a minimum 0.1°C temperature difference from the background, was between 2 and 4 seconds, therefore approximately equal to the duration of the heating pulse applied. This is more than sufficient for identifying possible abnormal features (e.g., damage). At 10 Hz, the acquisition rate adopted in this work, a few dozen images were recorded during transient ime. The temperature decrease during cooling down up to the end of the transient time for the four features observed is reported in Figure 1.

The heating uniformity obtained, which is directly correlated with the POD [5], was rather poor in the case of the presence of ridges (cases A and B), whilst it was much better in the case of folding lines (case C), and in the case of smaller features, such as the rotograved number in case D (see Figure 2). In this latter case, however, there is an excessive sensitivity to depth, supposed to be roughly constant across the feature, which may possibly result in false indications.

This procedure resulted also in the detection of a quasi-circular defect on the surface of the cardboard, with average diameter around 0.5 mm, corresponding to 20 pixels. The corresponding IR thermogram is shown in Figure 3. The defect had at least a difference from the surrounding background of approximately 0.5°C in the highest resolution image recorded during transient time.

4. Conclusions

The preliminary tests show that, provided a uniform heating is achieved, microfocus thermography can offer some possibilities of defect detection, even on film-like materials with low conductivity, such as cardboard. Transients in the order of few seconds can be obtained, which allow measuring temperature gradients sufficient for damage detection. This is more easily achieved for regions including linear features, where a possible depth variation, revealing a defect, is more consistently detected, than in those including circular features. Here, a similar depth variation can result in very different thermographic image, as a result of the emissivity not being constant. In spite of these limitations, it can be suggested that detection of defects smaller of 1 mm on a poorly conductive grey-body material is possible.

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Features	**Description**	**Max. depth (µm)**	**Max. transient time (s)**	**Max. ΔT (°C) ("undefected regions")**
A	Shallow ridges	150	3.8	1.8
B	Deep ridges with scratch	250	2.2	2.3
C	Two shallow 0°/90° folding lines	100	3.5	0.9
D	Rotograved number	60	4.0	2.5

Table 1 Features observed by IR thermography

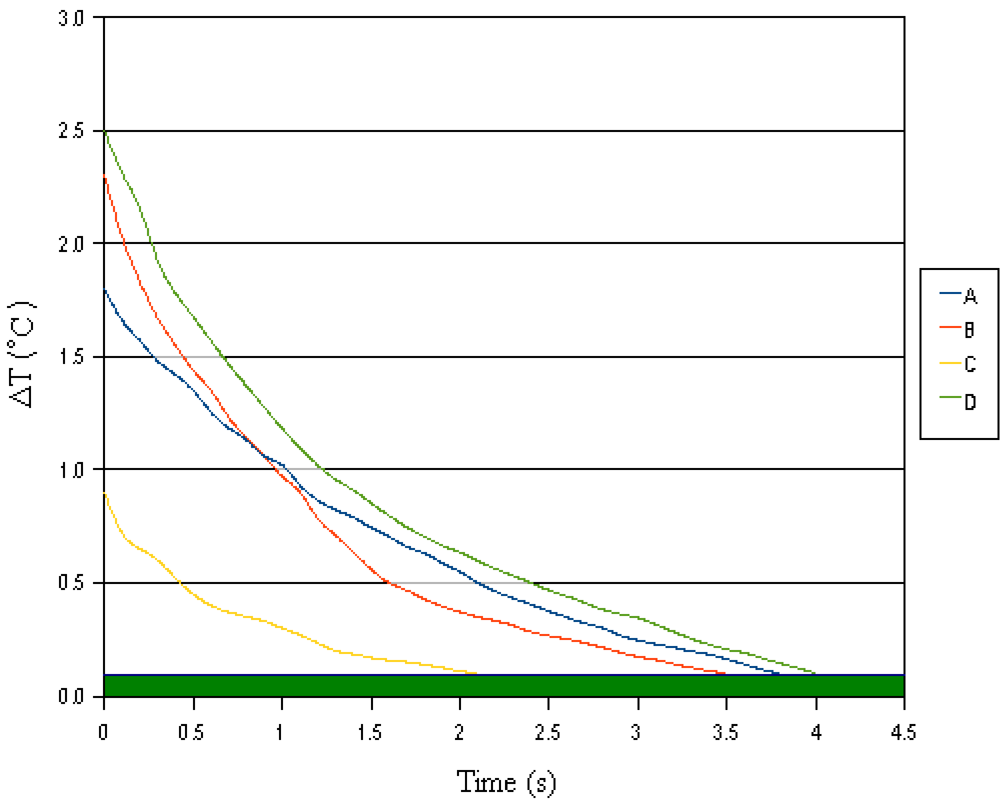

Figure 1 Decrease of max. ΔT (°C) for the four features with respect to background (the area below 0.1°C is highlighted in green)

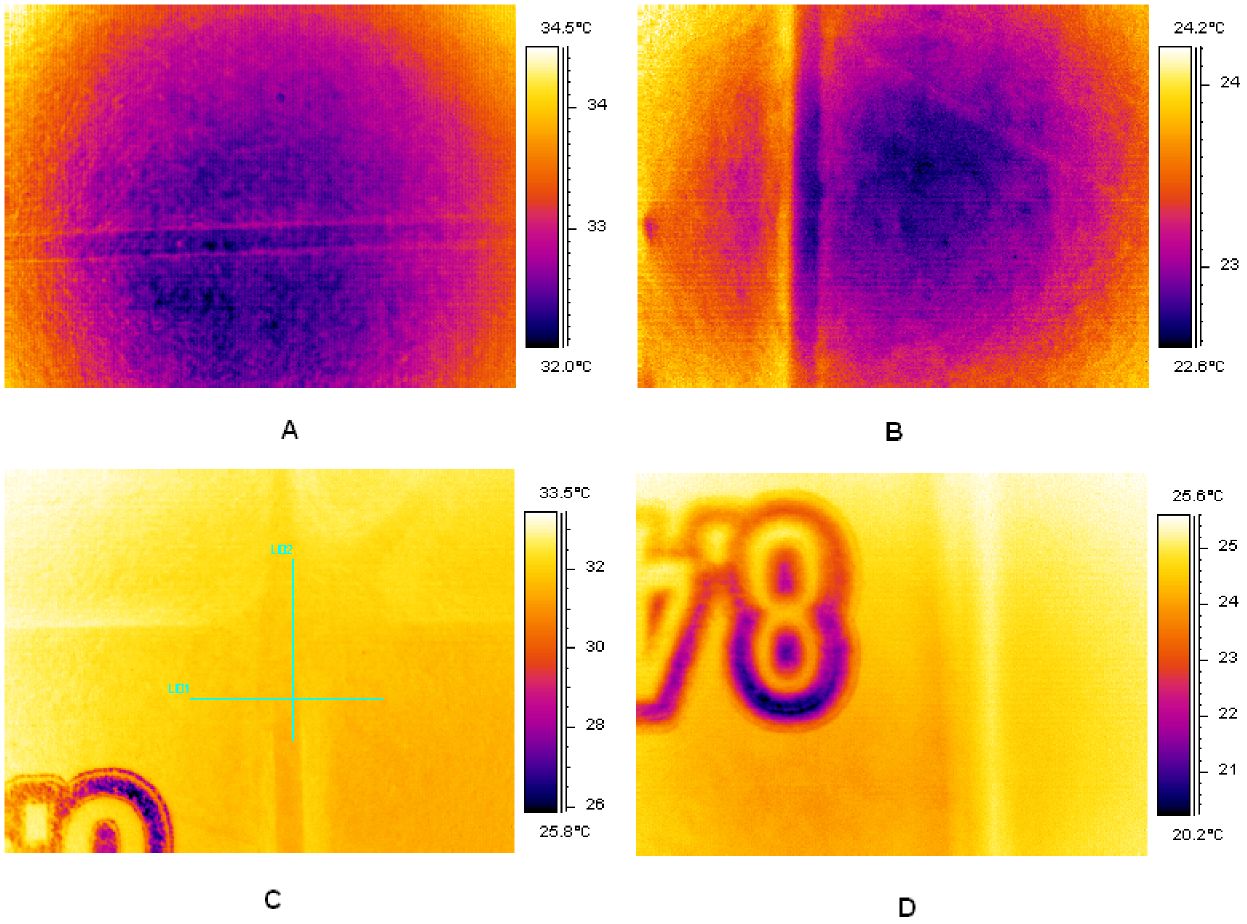

Figure 2 Typical IR images for the features observed

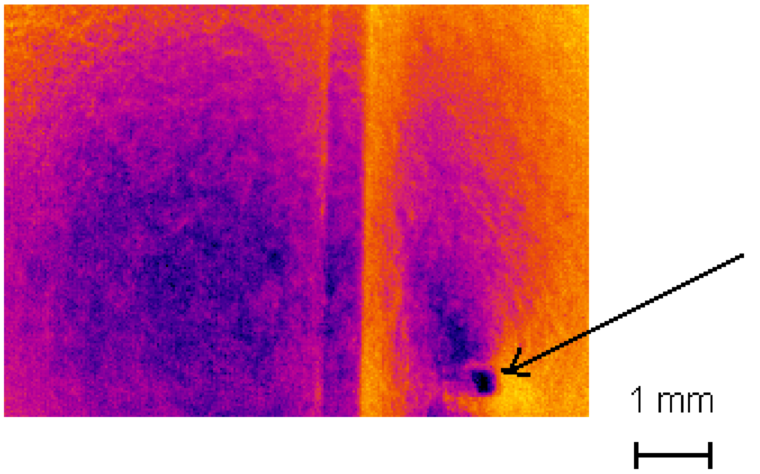

Figure 3 Detected surface defect (indicated by the arrow)