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Robot-assisted laser thermography: towards automatic characterization of surface defects

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Abstract (Arial, 9pt, bold)

By means of laser thermography, surface defects, in particular surface breaking cracks, can be detected with high sensitivity. Basically, this requires a focused heat source (high-power laser), a thermographic camera and a relative movement between laser and test object, as well as a suitable evaluation algorithm to distinguish between surface defects and defect-free areas. In this paper we report on a method in which the relative motion is realised by a robot to fully inspect large and non-planar test objects such as turbine blades. We show the influence of the excitation laser, which can be varied in terms of spot geometry, wavelength, and scan scheme, and we demonstrate our evaluation algorithms with the aim of automatically detecting surface defects.

1. Introduction (Arial, 9pt, bold)

Laser thermography has shown to be accurate and versatile for detection and characterization of surface breaking cracks.[1-5] Most applications of laser thermography for non-destructive testing of components were usually performed with manual or semi-automatic setups in laboratories. Nevertheless, in the last decades more and more groups are interested in building automatic thermographic setups to test many specimens or very large ones.[2, 4] Additionally, new challenges emerge by using automated thermographic systems, like processing high amounts of data (thermograms), correlating the inspected zones with the actual specimen or a CAD model, efficient path planning for inspection of a given component, etcetera.

2. Methods (Arial, 9pt, bold)

In the last decade, Schlichting et al.[6] proposed an efficient algorithm to detect surface breaking cracks analysing the thermographic film recorded from a flying spot test. It consists in computing the first derivatives along the horizontal and vertical directions on each thermogram. Then, the resulting “derivative films” are concatenated and sorted at once (each pixel is sorted ascending in $\partial T/\partial s$, where *s* denotes the spatial direction). Sorting both derivatives together assures that the most sensitive one is chosen. Therefore, all surface breaking crack indications are combined into single images. Even though, the length of the resulting sorted “derivative film” is twice of the acquired thermographic film, authors showed that the best results are obtained within the first few obtained images (or frames). We refer to this approach as the *Sobel-based algorithm*.

Recently, we have developed a similar algorithm for automatic surface defect detection. We refer to this one as the *Canny-based algorithm*.[7, 8] Briefly, each pixel on the thermogram is sorted from its lowest to its largest measured temperature (or temperature rise) in the film. Next, the sorted film is reduced in length, by keeping only the last N_{scan} images (the number of frames required to scan the imaged zone) and dropping the rest. Each frame in the reduced film is normalized in the gray-level. After this, a Gaussian blur filter of kernel 5×5 is applied to the normalized sequence. The Canny filter is applied to the denoised film. Now, each pixel on the image is averaged along the length of the resulting filtered film. At this stage, the processed N_{scan} “edge maps” are reduced to a single “edge map”. An averaged thermogram obtained from the full film is normalized according to the gray-level and merged with the edge map to show the detected surface defects on the inspected zone.

3. Current and future work

We are currently applying the described methods in combination with a six-axis robot arm to characterize surface defects on turbine blades. Our aim is not only to manually teach the robot to scan a given complex specimen, but also (and mainly) to build a “digital twin” of our experimental setup to perform simulations offline, which can then be carried out in the laboratory with good accuracy. Further on, we are continuously improving the evaluation algorithms, since collecting large datasets will enable us to apply AI-based methods which will allow for an automated classification of the found defect indications into the different defect classes and false indications, e.g., due to surface anomalies. In addition, the continuous development of laser technology over the last few years has also allowed us to improve testing performance in terms of increased sensitivity and/or testing speed.

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