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Scanning pulse phase thermography with changing scanning speed

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Abstract

This work aims at non-destructive detection of surface defects in metallic specimens (e.g., railway track components) via pulsed inductive thermography on a moving device. A new approach for scanning long specimens with changing speed has been developed. Steel specimen is heated with an inductor and the surface temperature is recorded via an infrared camera. It has been shown earlier [1] that the evaluation of the temporal changes in the temperature by Fourier transformation to phase image reduces negative effects such as inhomogeneous emissivity. Such a transform requires computing the temperature change over time for each spot on the specimen. This further means that the whole recorded image sequence has to be reorganised. The developed method uses a referencing object visible in each frame so that an adjustment can be performed with image registration. Therefore, changes in velocity during the scanning process are possible which enables also a manually performed scan of the specimen.

Measurements of various work-pieces have been performed both on a scanning test rig with an inductive linear heating source (see Fig.1.a) and on a scanning test rig with a U-shaped inductor (see Fig.1.b). On both test rigs manual scanning and scanning with a constant velocity is possible. In the case of a specimen with subsurface defects the linear heating test rig has been used. A 9 mm thick metal plate with flat bottom holes has been placed on the test rig in such a manner, that the flat bottom holes were facing away from the heat source as well as the infrared camera. The flat bottom holes have diameters of 8 and 10 mm. A metal ruler is placed on the linear table and used for image registration.

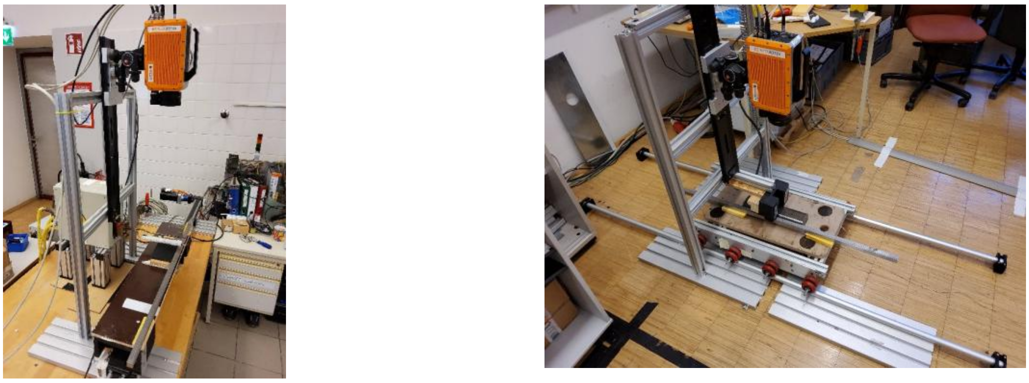

***Fig.1. a.)** Test rig for scanning with an inductive linear heating source; **b.)** Test rig for scanning with a U-shaped inductor*

In a first measurement the linear table has been moved manually and the cooling process of the metal plate after the heating has been recorded with the infrared camera. The shift in consecutive frames of the recorded image sequence is registered using MATLAB's image processing toolbox [2]. Using the metal ruler in each frame the pixel-movement and velocity is calculated. To compute the current displacement (see Fig.2.a) as well as the current speed (see Fig.2.b) during manual scanning the ratio of pixel per mm is measured using the image of the metal ruler. The maximum speed of this specific manual scan was about 59 mm/s.

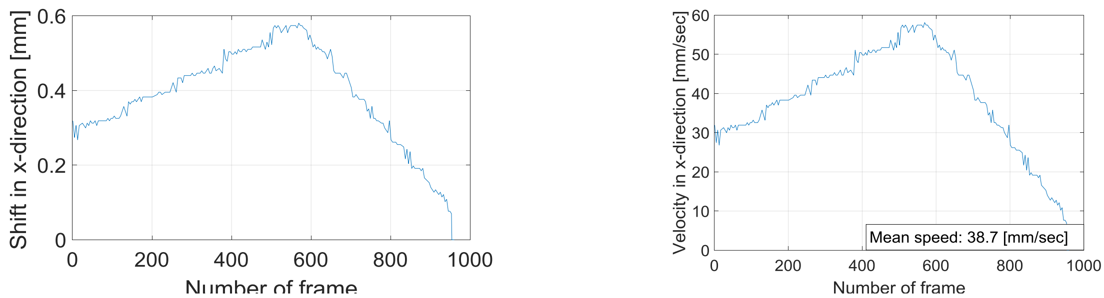

***Fig.2. a.)** Shift of the metal ruler in consecutive frames in mm; **b.)** Calculated current velocity of the linear table in mm/sec using the shift between consecutive frames and the frame rate of the camera*

According to this pixel-shift, each frame of the image sequence is shifted and a new image sequence is created with quasi no movement of the specimen. By performing a pixel-wise Fourier transformation on the new image sequence a phase image is created (see Fig.3.). The detectable flat bottom holes in the phase image (see Fig.3.) have a remaining wall thickness of 3 to 6 mm from left to the right, consecutively. Furthermore, measurements with constant speed were performed and evaluated as shown in previous work [1] in order to compare the performance of both techniques.

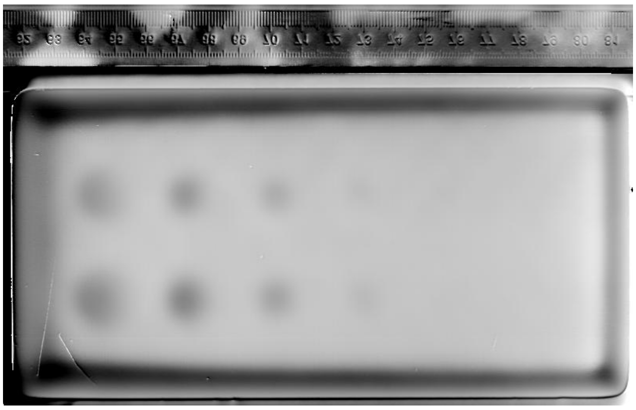

Fig.3. *Phase image of a steel workpiece with flat bottom holes obtained from a manual scan; flat bottom holes in upper row with 8 mm diameter; flat bottom holes in lower row with 10 mm diameter*

For detecting surface cracks, a U-shaped inductor was used, as shown in Fig.1b. The result of such a measurement on a rail piece with squats is presented in Fig.4, revealing the specific surface defects known as squats.

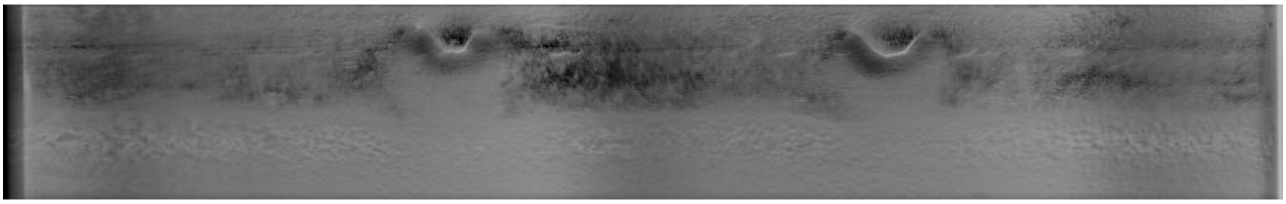

Fig.4. *Phase image of squats on a rail piece created from a manual scan*

As conclusion it can be stated that scanning inductive thermography can be excellently used to detect subsurface and surface defects in long metal workpieces. Temperature images are affected by inhomogeneous heating and by inhomogeneous surface properties as emissivity, which makes it difficult to distinguish between artefacts and real defects. To avoid these negative influences, the recorded infrared sequence is reordered, the temporal change of the temperature is determined to each position and then a phase image is calculated using Fourier transformation. In many practical applications it is not possible to ensure a constant scanning speed. For such situations a new method has been developed and presented, where an additional object, e.g. a metal ruler is used to register the images, and determine the actual speed from the images themselves. In further step this information is used to shift the recorded images before a phase image is calculated. Future work will focus on (a) the velocity limits of such a scanning setup depending on the used equipment and (b) the quantification of the detected defects, i.e. the measurement of length and depth of surface cracks as shown in previous work for a static setup [3].

REFERENCES

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