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Induction thermography with automated defect detection in comparison with magnetic particle inspection

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Abstract

A study with in total 200 forged steel parts was performed in order to compare the testing reliability of automated thermographic testing and magnetic particle inspection. A robot supported thermographic inspection station was built up. The thermographic phase images obtained were analysed by an automatic defect detection procedure based on machine learning techniques. Results of magnetic particle inspection served as a reference. A good testing reliability was found.

1. Introduction

In spite of steady improvements of manufacturing processes it is possible that surface defects like cracks occur in forged steel parts. For safety relevant mass parts, the present standard in industry is magnetic particle testing. This technique needs trained inspectors, requires chemicals and visual testing under UV illumination. Often the results are not fully documented. An alternative is induction thermography (or pulsed eddy current thermography). This contribution presents the results of several studies comparing the testing reliability of induction thermography with magnetic particle testing.

2. Automated testing station

The thermographic testing technique can be an economic alternative to conventional testing, if it is fully automated and it achieves an at least comparable testing reliability. A robot operated testing station was built up with a stationary inspection head consisting of infrared camera and inductor. The steel parts were grabbed by a magnet holder mounted on the arm of the robot (figure 1).

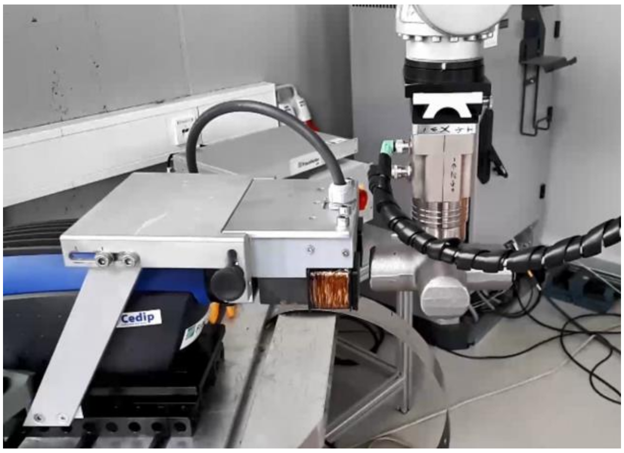


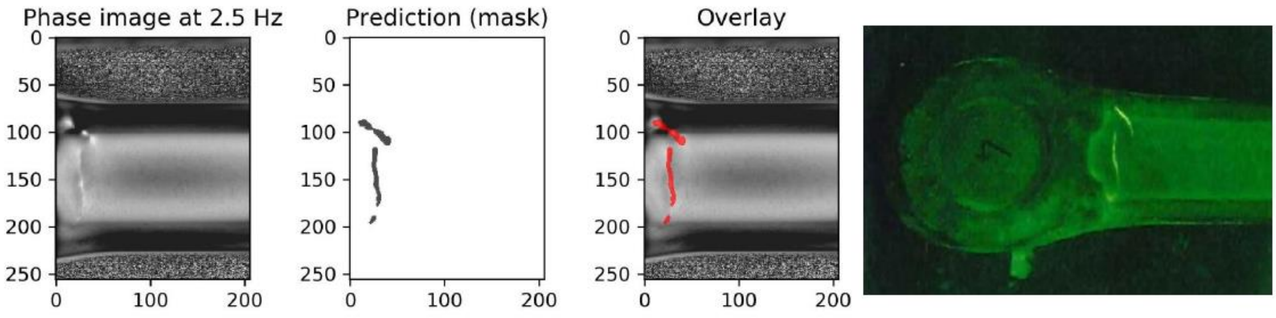
Fig. 1. *Thermographic inspection station with test object held by a robot*

After teaching, the robot took a test object out of a transfer station, kept it in short distance of the inspection head for a measurement and then positioned it to the next region of the sample. The sample was tested on the complete surface in up to 28 single measurements, before it was delivered back to the transfer station.

3. Defect detection using machine learning algorithms

Form selected types of forged parts like con-rods testing lots mixed from “in order” and “not in order” parts were compiled. The parts were tested by induction thermography. From the recorded thermographic image sequences, pulse phase thermography images were calculated in a pre-processing step. Half of these images served as training data for a neural network of type U-Net [1]. The number of training data was increased artificially by image transformations. After training of the network, the other half of data was then analysed automatically for crack-like defects. Finally, the results of automatic testing were compared with the results of conventional industrial magnetic particle testing for mass products.

Figure 2 shows a crack zone on a con-rod detected by the algorithm along with the corresponding image from magnetic particle testing.



a) b) c) d)

Fig. 2. *Thermographic phase image of a con-rod showing cracks (a), detected defect mask (b), mask in overlay with the phase image (c). Result of magnetic particle testing (d)*

4. Results

Figure 3 shows the comparison of the number of defect indications (given by the length of the bars) by thermography and magnetic particle inspection. Large (dark blue), middle (blue) and weak (light blue) indications detected by induction thermography are distinguished.

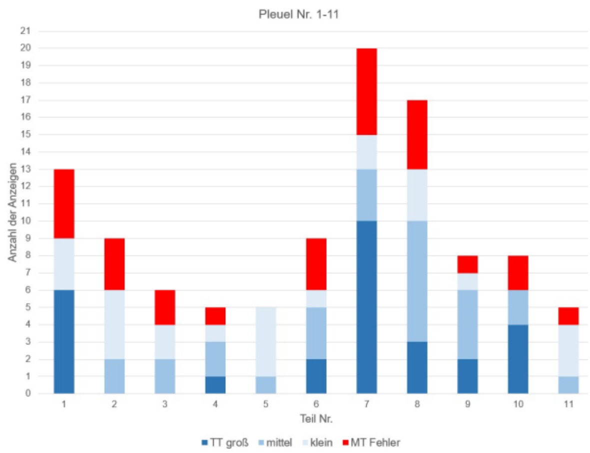


Fig. 2. *Statistics of the number of indications detected by thermography (blue bars) and magnetic particle testing (red bars) over 11 con-rods*

If one accepts magnetic particle testing as a reference, depending on the type of test object a true positive correlation of 68% to 82% was achieved. If weaker thermography indications are also considered, the correlation is even better. There were no false positive results. Indications not detected by induction thermography, but by magnetic particle testing were later analysed destructively by metallographic inspection. The cracks verified were less than 150 µm deep and regarded as not to be critical.

The present solution still requires too much inspection time for testing forged mass products. In the contribution, we will discuss concepts to increase testing speed.

REFERENCES

[1] O. Ronneberger, P. Fischer, T. Brox, 'U-Net: convolutional networks for biomedical image segmentation medical image computing and computer-assisted intervention (MICCAI)', Vol. 9351. Munich, Germany: Springer, LNCS; 2015. p. 234–241.