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Qualification of active thermographic methods for testing welded joints

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Abstract

Over the past years, significant progress has been made in the application development of active thermography for the inspection of welded joints of semi-finished metal products. Various research projects have demonstrated the potential for detecting the quality-relevant flaws in these joints. With the simultaneous steady improvement of the system technology of active thermography, it has also been possible to increasingly implement pilot solutions in industrial applications. The next logical step is to incorporate the testing technique into the relevant standards for the non-destructive evaluation of welded joints so that the technology can be applied more widely and also in less automated applications. However, the integration of active thermography into the testing standards for the non-destructive evaluation requires detailed knowledge of detection possibilities as well as detection boundaries. Therefore, this paper presents the results of a study that focus on the qualification of the three most matching thermographic methods, as an alternative evaluation technique for welds. It is known that active thermographic methods differ in the excitation source. Here are chosen the most promising for the testing of metal components. The focus in this study is mainly on the application of induction-excited thermography, however, ultrasonic excitation as well as laser-based excitation are considered as well. The approach for the qualification of active thermographic methods for testing welded joints is presented and may be adopted as a standardized method for the qualification of NDT-methods in general.

To qualify the thermographic methods, a three-step approach based on artificial as well as realistic defects was chosen.

The first part of the study deals with the manufacturing of representative specimens to determine the possibilities of different thermographic methods. This should be done by selecting the materials used (steel and aluminium) and the thicknesses of the semi-finished products as close as possible to reality and relevant to the standards to achieve a high relevance and good comparability to other NDT procedures standardised for welded joints.

There are some challenges that must be meet during the specimen preparation to achieve representative and reproducible specimens with realistic defects. Based on an evaluation of typical welding defects, two groups of defects (cracks and voids) were identified as the defects most likely to be detected by thermographic measurements. Specimens containing those defects were manufactured using different approaches. First of all, specimens with defects were manufactured using variations of fusion welding (MAG). The welding processes were manipulated to obtain defects that variated in size and location. The manufactured defects covered a wide range of sizes and it could be shown, that it is possible to manufacture specimen with realistic defects. This specimens were used to demonstrate the capability of the thermographic techniques to detect typical welding defects. However, these methods lack in controllability and reproducibility, which is especially critical for inner defects. Therefore, alternative approaches based on laser powder bed fusion (LPBF) and friction stir welding were applied to manufacture specimens to achieve a higher degree of controllability and reproducibility for those defects. It can be shown, that artificial defects resembling real defects in size and location can be manufactured. These defects were the used to examine the detection limits for inner defects.

The second part deals with the thermographic testing of the specimens. The specimens were examined using three different thermographic techniques. For the comparability and repeatability of the test results, a special test stand was designed in which precise positioning of the welding specimens is possible. The test stand can be equipped with different IR cameras and excitation sources to enable comparisons to be made. In addition, the IR recordings can be easily and reliably calibrated metrically with the help of a specially developed method and associated calibration bodies. Thus, the test results can also be compared well with those of other NDT methods.

The detectability of artificial as well as realistic defects by those techniques is displayed and challenges as well as limitations are addressed. The results show the high potential of all considered thermographic techniques to detect surface breaking, two dimensional defects as cracks as well as incomplete penetrations. In contrast, it can be shown, that the detectability of relevant inner defects is limited to surface near defects. Based on the results, the detection limits and limitations for the different testing techniques are derived and requirements for the implementation of thermographic testing of welds are discussed. Based on the results, the requirements on a testing system can be derived and recommendation concerning the testing procedure can be made.

Finally, the different thermographic testing methods are assessed regarding their potential as a suitable testing method for the evaluation of welded joints by comparing the results of the thermographic tests to the requirements defined in the testing standards as well as the results of the established testing techniques. Based on this it can be recommended, to introduce thermographic testing for the testing of welds. It can be shown, that the thermographic testing methods are well suited to detect surface breaking defects and therefore, should be included in the standards for

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the evaluation of welds. An exemplary result of the qualification is shown in Figure 1. In case of inner defects, the suitability of thermographic methods is limited as all the testing methods can detect all relevant welding defects due to the high requirements regarding the size of the defects to be detected specified in the existing testing standards for the evaluation of welds.

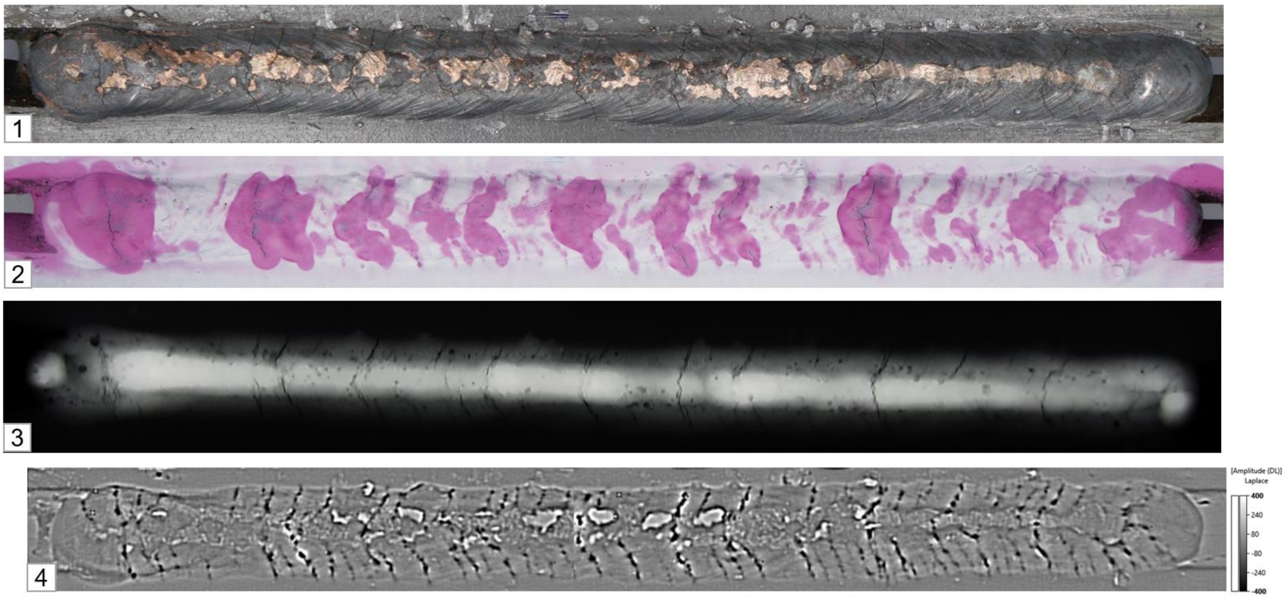

Figure 1: *Results of the qualification for induction excited pulse-phase-thermography (1: VIS-image of Weld; 2: Penetrant testing of weld, 3. Radiographic testing of weld and 4. Thermographic testing by induction-excited pulse-phase-thermography)*