Abstract of doctoral dissertation

Detection of discontinuities in plates made of nickel-chromium and aluminum alloys utilizing eddy current non-destructive evaluation and artificial intelligence algorithms

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The doctoral dissertation focuses on the subject of non-destructive testing of conductive materials. The objective of the study was to improve and refine the defectoscopy technique utilizing eddy currents to enhance the likelihood of identifying flaws while simultaneously minimizing the occurrence of false indications in nickel-chromium and aluminum alloy plates.

The initial phase of the study concentrated on developing and selecting the suitable excitation systems used in eddy current testing. In order to generate an alternating electromagnetic field, permanent magnets (by rotary motion) were employed. Subsequently, the excitation coils and the modified MFES-ECT (Multi-Frequency Excitation and Spectrogram Eddy Current Testing) technique were employed. The coils were driven by a waveform consisting of several sinusoids with varying frequencies, amplitudes, and phases. The lower frequency components of this signal facilitated the identification of defects situated at greater depths. However, the dispersion of eddy currents over a broader area resulted in a loss in the precision of the measurements. Greater measurement precision can be achieved with higher frequencies. However, identifying and characterizing defects located deep within the material becomes challenging since the currents do not penetrate as deeply.

A novel technique, PMFES-ECT (Pulsed Multi-Frequency Excitation and Spectrogram Eddy Current Testing), has been introduced to enhance measurement precision. This method combines the benefits of the multi-frequency method (MFES-ECT) and the pulsed method (PECT). It specifically enables the generation of denser eddy currents in the materials being tested, resulting in higher signal-to-noise ratio values. Additionally, the PMFES-ECT technique is considerably more energy-efficient, enabling its application in portable devices.

The eddy current sensors were simulated in both two-dimensional and three-dimensional systems, utilizing the Finite Element Method (FEM). Several simulations were conducted in both the time domain and frequency domain. The simulations' findings were employed to validate the concept of sensor functionality.

The subsequent phase was concentered on the processing of the acquired signals in order to achieve a more precise characterization of the flaw in the tested material. Noise reduction in the signals was achieved through the implementation of digital signal processing techniques. Additionally, the quality of these signals was enhanced by the development of functions that approximated them.

Artificial intelligence replaced the operator and diminished the time required to analyze and depict the flaw. The k nearest neighbors method was selected for its high efficiency. The training dataset for the k-NN algorithm was generated using the outcomes of a set of three-dimensional FEM numerical simulations of the eddy current sensor system. These simulations used a conductive plate with simulated flaws. Multiple dimensions of the defect were replicated, including different lengths and depths. A classification model was developed using the provided database and optimizing the settings of the k-NN algorithm. This model was subsequently evaluated on actual flaws observed in the tested object.

The research revealed that in the eddy current flaw detection method, the effectiveness of detecting and identifying discontinuities in nickel-chromium and aluminum alloy plates can be increased by selecting the appropriate excitation system and measuring sensors and further enhanced by utilizing artificial intelligence algorithms. Additionally, this approach also reduces the inspection time.

Keywords: non-destructive testing, eddy current testing method, finite element method, artificial intelligence, k nearest neighbors

19.06.2024