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Advantages of Using Eddy Current Array for Detection and Evaluation of Defects in Aviation Components

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Abstract
This article examines the potential of Eddy Current Array (ECA) as a non-destructive testing (NDT) technique for aviation components. Experimental investigations were conducted using a specially prepared sample with various defects. The scanning results demonstrated ECA's enhanced detection sensitivity, high inspection speed, and ability to characterize defects. The study emphasizes the need to optimize the inspection process and utilize automated subsystems for signal filtration and result evaluation. The findings support the adoption of ECA as an effective NDT technique in the aviation industry, contributing to improved safety and reliability. This research provides valuable insights for the development of guidelines and standards, enhancing the overall efficiency of aviation inspections.

Keywords: Eddy Current Array, non-destructive testing, aviation components, defect detection, inspection process optimization, reliability

1. Introduction

The aviation industry demands high levels of safety and reliability, making effective inspection and evaluation of components a critical aspect of maintenance and quality control processes. Detecting defects in aviation components is of paramount importance to prevent catastrophic failures and ensure the optimal performance of aircraft systems. Traditional inspection methods, such as visual examination and manual testing, have limitations in terms of accuracy, efficiency, and the ability to detect hidden defects. As a result, there is a growing need for advanced non-destructive testing (NDT) techniques that can provide more accurate and reliable defect detection capabilities [1, 2].
One such advanced NDT technique that has gained significant attention and recognition in recent years is the Eddy Current Array (ECA) inspection method [1, 3]. ECA offers numerous advantages over conventional techniques, making it an attractive solution for the detection and evaluation of defects in aviation components. This article aims to explore the advantages and potential of ECA in enhancing the safety and reliability of aviation systems.
Advantages of Using Eddy Current Array:

- Enhanced Detection Sensitivity: ECA combines multiple closely spaced coils in an array, allowing for improved coverage and increased sensitivity to small defects. This enables the detection of defects that may go unnoticed by traditional inspection methods, enhancing the overall effectiveness of inspections [4].
- High Inspection Speed: ECA's ability to simultaneously scan multiple channels and collect data in a single pass significantly reduces inspection time. It offers faster

inspection rates, making it suitable for large-scale inspection campaigns and reducing aircraft downtime during maintenance [5].

- Defect Characterization: ECA provides information about the size, shape, and orientation of detected defects. By analyzing the amplitude and phase information from the collected signals, it is possible to accurately characterize the nature of the detected defects, aiding in their evaluation and subsequent decision-making processes [6].
- Quantitative Data Analysis: ECA produces digital data that can be processed and analyzed using advanced algorithms. This allows for quantitative assessment and precise evaluation of defect characteristics, enabling engineers and inspectors to make informed decisions regarding the acceptability and repair strategies for aviation components [7].
- Surface and Subsurface Defect Detection: ECA is capable of detecting defects both on the surface and within the subsurface of aviation components. This makes it effective for identifying cracks, corrosion, delaminations, and other hidden defects that may compromise the structural integrity of the components [6, 8].

To validate and further explore the advantages of Eddy Current Array for the detection and evaluation of defects in aviation components, experimental investigations have been conducted. These experiments involve the use of specially prepared sample with known defects, representing typical flaws that may occur in aviation components.

2. Experimental Preparation

2.1 ECA system

Eddy current array technology is known for its ability to drive multiple eddy current sensors positioned side by side in the same probe assembly [9]. This enables ECA to inspect large surface areas in a single pass, maintaining high resolution and improving both inspection speed and the probability of detection [10]. The results can be displayed using color-coded mapping (C-scan), which enhances inspection performance and analysis. An ECA system consists of three fundamental components: an instrument, software, and a probe.

In this study, the Olympus Omniscan MX eddy current flaw detector with an ECA probe (Fig. 1) was used. The employed ECA probe is of the flexible type, made of a PCB-based film, and consists of 32 coils, each with a diameter of 3 mm. The probe used in the probe is of the absolute type.

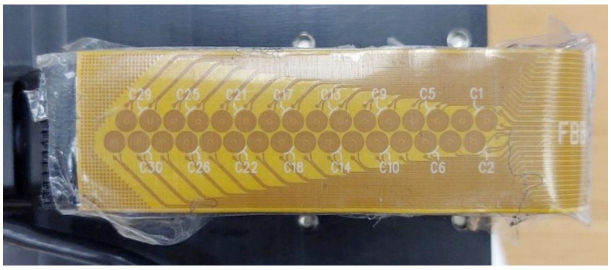


Fig. 1. ECA probe

The used flaw detector allowed for the control of the matrix sensors using a multiplexing pattern to avoid mutual inductance. It was also equipped with specialized software for creating C-scans and displaying the signals as a hodograph.

2.2 Testing object

Before the experiment, a sample made of the aluminum alloy 31T5 (AD31T5), commonly used in the aviation industry, was prepared. The sample has artificially created defects of various configurations and sizes. Fig. 2 showcases the prepared sample with the following dimensions: a length of 360mm, a width of 120mm, and a thickness of 5mm. This sample contains two types of defects: longitudinal crack-type defects (1-4 on Fig. 2) and circular defects with varying cluster densities (5-12 on Fig.2, Fig. 3a and 3b).

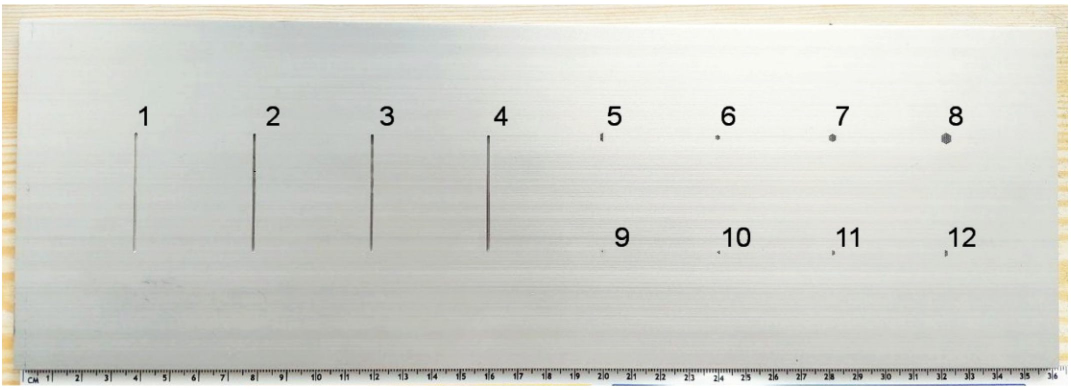
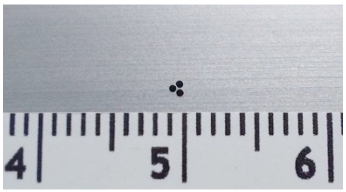
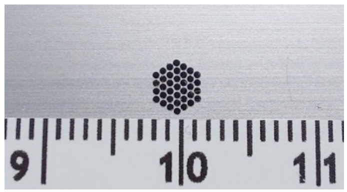


Fig. 2. Sample made of AD31T5 alloy (1 – 12: defects of various types and sizes)



a



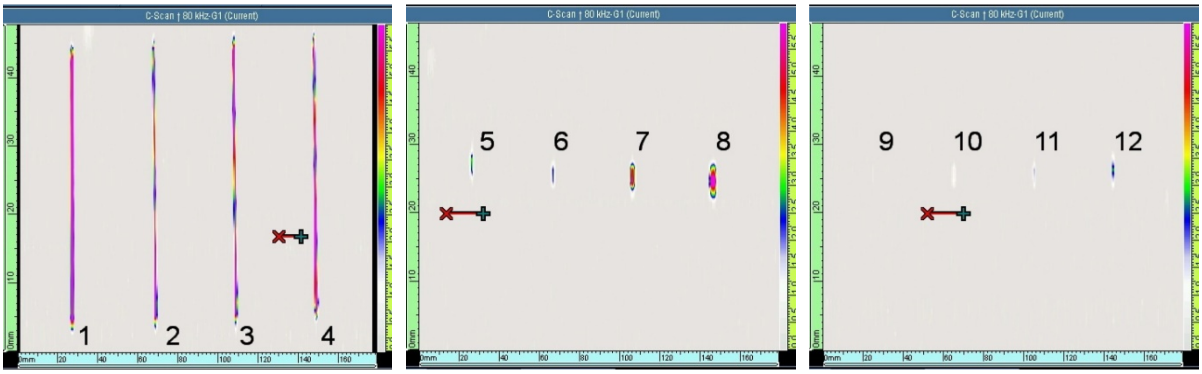
b

Fig. 3. Circular defects of varying cluster densities in sample (a – defect №10, b – defect №8)

The longitudinal defects have a width (B) of 1mm and penetrate the material with depths (h) ranging from 1mm to 4mm. The circular defects have a depth (hd) of 4mm and a diameter (d) of 0.5mm. These circular defects are positioned in different cluster densities adjacent to each other. However, it is worth noting that some sizes may be too small for testing using the available eddy current array equipment.

3. Result and discussions

The scanning results in the form of C-scans for parts of the sample are presented in Fig. 4 (for convenience, the scanning results are divided into three zones and the defect numbering from Fig. 2 is used). The following settings were used during the scanning process: scanning frequency of 80 kHz, excitation coils signal amplitude of 1 V and gain of 78 dB.



a b c

Fig. 4. Scanning results in the form of C-scans for sample sections

As seen from Fig. 4, the color representation of defects 9 and 10 (Fig. 4c) is least noticeable with the given scanning settings. Detecting defect 9, which is represented by a single hole with a diameter of 0.5 mm, is challenging without prior adjustment and calibration of the matrix transducer, indicating the necessity of selecting an optimal scanning mode for defects of such size. Additionally, the settings for displaying the results are also important, as adjusting the sensitivity level using the color scale can enhance the visualization of such defects, but there is a risk of noise and interference affecting the results.

4. Conclusion

The experimental data obtained from these studies provide valuable insights into the performance, reliability, and limitations of ECA, supporting its adoption as an effective non-destructive testing (NDT) technique in the aviation industry. Through the analysis of experimental results and the examination of various parameters' influence on inspection outcomes, the necessity of optimizing the inspection process and enhancing the capabilities of ECA for aviation component inspections is demonstrated. The findings from these experiments contribute to the development of guidelines, best practices, and standards for the application of ECA in the aviation sector.

In conclusion, the advantages offered by Eddy Current Array make it a promising technology for the detection and evaluation of defects in aviation components. Through experimental investigations and research, the capabilities of ECA can be further utilized, leading to improved safety, reliability, and efficiency in the aviation industry. The results of these studies prompt the exploration of signal-filtering possibilities at different stages of working with measurement outcomes. Additionally, considering the implementation of automated subsystems for selecting filter modes based on the evaluation of filtered results is worthwhile.

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