Enhancing Root-Deck Crack Detection in Orthotropic Steel Decks through Numerical Investigation of Eddy Current Techniques

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Abstract

Orthotropic steel decks in long-span steel bridges are susceptible to fatigue cracking, especially subsurface root-deck cracks. These cracks, hard to detect visually, can cause significant damage if unnoticed. Therefore, the early detection of these subsurface cracks is crucial in preventing further deterioration and ensuring the long-term sustainability of the bridge. In this study, a novel approach for the detection of subsurface cracks in orthotropic steel decks, utilizing new signal processing techniques based on eddy current technology (ECT), as well as optimizing the configuration of the ECT probes, is proposed. Through numerical analysis, response signals obtained from subsurface crack detection using ECT in frequency domains are extracted and analyzed with the proposed method to develop advanced feature extraction techniques that enhance sensitivity and improve the depth of subsurface crack detection. Additionally, various coil-based eddy current probes are examined to identify the most suitable probe configuration that offers robust performance in detecting subsurface cracks. The findings from this study contribute to the advancement of more effective strategies for subsurface crack detection in orthotropic steel decks by integrating advanced eddy current techniques, feature extraction methods, and optimized hardware configurations.

Keywords: Eddy current, root-deck crack, orthotropic steel deck, bridge maintenance

1 Introduction

The challenge of detecting root-deck cracks in orthotropic steel decks (OSDs) requires extra attention [1]. Traditional visual inspections often failure to detect these cracks due to factors like limited visibility, small initial size, complex geometry, and the presence of coatings [2], as shown in Figure 1. These undetected cracks can lead to rapid structural decline and even catastrophic failures [3]. To prevent severe bridge damage, it's essential to use advanced non-destructive evaluation methods for early, accurate, and reliable detection of these damages.

Eddy current technique (ECT), a promising technique in electromagnetic non-destructive evaluation and testing (NDE&T), is highly effective for detecting internal and subsurface damage in electrically conductive materials. ECT's strengths lie in its ability to identify subsurface cracks, handle surface irregularities, and provide fast data collection along with detailed defect characterization [4, 5]. Additionally, ECT is cost-effective and minimizes the need for extensive preparation, such as surface treatment before and after inspection, making it an ideal choice for examining orthotropic deck bridges. The frequency used in ECT significantly affects the results. Lower frequencies are better for subsurface damage while higher frequencies are suitable for surface damage [6]. Therefore, low-frequency ECT is commonly used for subsurface damage assessment. However, at low frequencies, both the spatial resolution and sensitivity of the detection coil and sensor are reduced due to the skin effect.

Therefore, the Swept Frequency Eddy-Current Technique (SFECT) is a promising variation of ECT that is particularly effective in identifying subsurface damage. SFECT stands out for its ability to detect defects across a variety of materials and flaw geometries. This adaptability is attributed to its use of multiple frequencies, allowing the

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