INVESTIGATION OF USABILITY OF FLUORESCENT AND RADIOLABELED LIQUID PENETRANT AS A NON-DESTRUCTIVE TESTING AGENT

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ABSTRACT

The fluorescent penetrant inspection (FPI) is a non-destructive method used for identifying and locating surface discontinuities. Traditional dye penetrant testing of surface cracks in metals has limited sensitivities to micro-scale surface defects. More recently, studies mainly aimed at developing a new generation penetrants which will be able to detect the micro-scale cracks in surface. In accordance with these purpose; detection of defects in metals can be inspected with fluorimetric and radioisotopic via Fluorescein Isothiocyanate (FITC) conjugation of ⁹⁹ᵐTc radiolabeled Escherichia coli (E.Coli). In this study, bacteria were conjugated with FITC which is a fluorescent dye in order to give fluorescent properties to E.Coli and then radiolabeled with ⁹⁹ᵐTc radionuclide by tin chloride reduction method and surface defects were detected by both fluorimetric and radioisotopic methods. This study will contribute to recent researches on the detection of surface defects or damage in micro scale by both these methods and will be gained a new perspective on existing applications. There have been very few papers related to our study. From this point of view, these studies will accelerate R&D activities where advanced technology and materials are used. This paper will also provide to the literature support for the recent years of organic bacterial penetrant studies and related researches.

Key words: Liquid Penetrant Testing (LPT), ⁹⁹ᵐTc Radiolabeled, Fluorescein Isothiocyanate (FITC), Escherichia Coli (E. coli).
1. Introduction

Non-destructive testing (NDT) plays an important and critical role in aviation, automotive and rail industry. It is also important for oil, gas, petrochemical and machinery industries. The main aspect of NDT is to examine defects in components, reduce failure and increase reliability. In recent times, they are not only used in product development, but also in the routine quality control during service. In this way, each component performs its function acceptable quality with a high degree of accuracy.

Today, there has been a certain number of research efforts expanded to new NDT techniques to meet the changing requirements and demands in a wide range of industries. However, micro and nano scale components are rapidly becoming a part of the products at various stage of the manufacturing process. These products are not detectable by conventional NDT methods. The increasing of these products has resulted in significance trends in research and development of numerous methods of surface defects detection [1,2,3,4,5,6,7].

Liquid penetrant is widely used to examine surface defects in any industrial product for many years. It is widely used for achieving high quality in aviation and automotive industry. This method became simple and cost effective testing capable to indicate the presence of surface cracks in material [8]. The penetrant testing were subject of research and evolved until the late 1990s. Thereafter, several research have been conducted on penetrant dye techniques. One of the important contribution to the literature has been made by Mahendran et al. They showed a methodology to visualize defects by naked eye using nanofluids to examine surface defects in ferromagnetic material [9]. Siorees et al investigated the potential use of magnetotactic bacteria for application in NDT. Their experiments have shown that the bacteria can be used as a penetrant for detection of cracks and flaws in materials at a small scale [10]. More recently, a remarkably studies performed by Santos et al. In this research, they presented a new NDT technique based on bacterial cell films to identify micro surface cracks. The experiments showed that the bacterial cells can be used to detect micro size surface cracks in stainless steel and aluminium alloy [11,12].

This study aims to present a new bacteria to show micro cracks on the surface of the samples. For this purpose E.Coli bacteria conjugated with FITC fluorescent dye for fluorimetric imaging and were radiolabeled with Technium-99m (99mTc) radioisotope. E.Coli bacteria is preferred because of biosafety Level-1. 99mTc is the most common radioisotope used in medical diagnostic. It has been prefered for its properties such as short half-life and low gamma energy. This paper focuses on detecting micro cracks in samples using by fluorometric method and radiation measurements. In this respect, we investigated the potential use of E.Coli bacteria for detection of micro cracks on metal surface.

2. Experiments

2.1 Conjugation of E.Coli with FITC

E.Coli bacteria was conjugated with FITC according to Nakamura and Santra et al. [13,14].

2.2 Radiolabelling of FITC Conjugated E.Coli

FITC conjugated E.Coli bacteria was radiolabeled with 99mTc and quality control of 99mTc radiolabeled FITC conjugated was done by using Diniz et al methods [15]. The yield of bacteria labeled with 99mTc is of 98±0.5%.
2.3 Application of FITC Conjugated E.Coli Bacteria and $^{99m}$Tc Radiolabeled FITC Conjugated E.Coli Bacteria on Test Material

Aluminum plate (10 mm thickness) used in the experiment are presented in Fig. 1. Cracks were created by scratching the plate. The scratches at the plate surface ranged in depth from 100 to 600 microns. FITC-labeled E.Coli bacterial suspension as penetrant was applied to the surface of the test material titled TM1. The penetrant remains on the TM1 for a predetermined time (dwell time), here five minutes. After deposition of the E.Coli bacterial suspension, each defect on the sample was observed by fluorescence microscopy using Olympus BX53 microscope. Fig. 3 is an enlarged view of scratched line in the TM1 under fluorescence microscope. The second step in the experiments is to apply $^{99m}$Tc radiolabeled FITC conjugated E.Coli bacteria to the surface of the test material (TM1). The surface of TM1 is divided into four areas: (Fig. 2). These are named TM1a, TM1b, TM1c and TM1d. Radioactivity measurements from these locations were performed by CdTe detector as shown in Fig. 4.

3. Figures

![Image 1](image1.png)

Fig 1: Test material 1 (TM1).

![Image 2](image2.png)

Fig 2: Picture of TM 1 for fluorimetric and radioisotopic experiments.
<table>
<thead>
<tr>
<th>Test Locations</th>
<th>TM1a</th>
<th>TM1b</th>
<th>TM1c</th>
<th>TM1d</th>
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<tr>
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<td><img src="image15" alt="Image" /></td>
<td><img src="image16" alt="Image" /></td>
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Fig 3: Enlarged view of fluorometric images of conjugated E. coli bacteria with FITC.

![Image](image17)

Fig 4: Measured radioactivity levels in surface of TM1.
Fig. 3 depicts scratches ranged from 300 to 600 micron where FITC-labeled E.Coli bacterial suspension are located, indicating the defects. From this figure it can be seen that bacteria suspension penetrate and adhere to defects. Defects were simulated by scratching as a line aluminium sheet (TM1). Each line scratch has different depths but same width. Figure 4 shows radioactivity counts for each line scratches with CdTe detector. It is observed that TM1a and TM1c values is slightly less than the expected. From the point of view, radiolabelled bacterial suspension is not enough to penetrate or spread out over the surface.

4. Conclusions

This study has presented a new approach to detect micro surface cracks using E.Coli bacterial suspension. From the point of view of a practical application, the experiments also proved that FITC conjugated and radiolabeled with $^{99m}$Tc E.Coli bacteria were effective in examining surface for detecting and identifying cracks. Experimental results showed that cracks ranging in depth from 100 to 600 microns in test block TM1 were successfully detected. A good agreement was found between fluorometric and radiation measurements. This paper also may provide a significant contribution to the current literature and related studies.

5. References