CHARACTERISATION OF CORROSION PITTING AND INDUCED FATIGUE CRACKING USING X-RAY MICROGRAPHY

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Summary: In this study the mechanism of surface and fatigue cracking initiation from corrosion pits is evaluated by using three-dimensional X-ray images in two case studies.

1. INTRODUCTION

Pitting corrosion is a form of localized corrosion that under cyclic loading may result in fatigue cracking and ultimately final failure of components. Therefore, the pit-to-crack transition is a significant part of the fatigue failure process [1]. In order to develop reliable fatigue crack predictive models, there is a need to understand the mechanisms involved in the pit-to-crack transition. Although steel alloys are susceptible to pitting corrosion in aggressive environments, a fundamental understanding of pit-to-crack transition is not yet available for steels [2]. Previous studies have investigated this transition stage using methods such as Scanning Electron Microscope (SEM) to probe the surface of the material intermittently during and after fatigue testing. However, observation of the cracks initiated from the wall or base of the pit is not possible using this approach. In recent years there has been an increasing interest in characterising materials using the X-ray Computed Tomography (CT) and the applicability of this technique in materials science is well established [3-5]. The present paper describes our efforts to use a CT scan facility to investigate the pit-to-crack transition during fatigue testing of two complementary steel alloys (X65 and 316L grades) using an environmental test rig. This study provides new insights into the investigation of the corrosion fatigue process.

2. METHODOLOGY

Many researchers have utilised SEM to study the surface crack nucleated from corrosion pits. However, SEM is only capable of characterising surface cracking. A major advantage of the approach described in this paper is that by using X-ray microtomography (XRM) both surface cracks emerging from corrosion pits and internal fatigue cracks initiated from the wall or base of a corrosion pit can be detected. The experiments were performed at the National Structural Integrity Research Centre (NSIRC Ltd.) in Cambridge using a ZEISS Xradia 520 Versa instrument (Figure 1a). A bespoke test cell was constructed to conduct in-situ corrosion fatigue tests and allow XRM of specimens under load. Two different alloys, API5L-X65 pipeline steel and 316L grade stainless steel, were used to prepare dog-bone tensile specimens. To optimise the resolution of X-ray images the cross sectional area of the test section was reduced to $3\times4mm^2$. Prior to start the corrosion fatigue tests, a corrosion pit was created on the centre of each sample by using VesaScan equipment which uses an electrochemical method to make corrosion pit. Figure 1b &1c show two typical images taken from a corrosion pit in a 316L sample. The pre-pitted samples were then placed in the environmental cell and subjected to fatigue loading in the test media. The evolution of the corrosion pit region was characterised by XRM after the desired number of cycles, to probe the

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pit-to-crack transition process.

3. CLOSING REMARKS

This study set out to investigate the pit-to-crack transition in two different materials under combined action of corrosion and fatigue. The findings of this research provide insights for a better understanding of the mechanism of pit-to-crack transition stage and also the remaining time from corrosion pits to fatigue cracking. A key strength of the present study is characterisation of corrosion pits using X-ray microtomography, which allows us to monitor the inner and exterior surfaces of specimens containing embryonic fatigue cracks initiated from corrosion pits. More tests are planned to investigate the pit-to-crack transition in different frequencies, stress levels and corrosion pit sizes.

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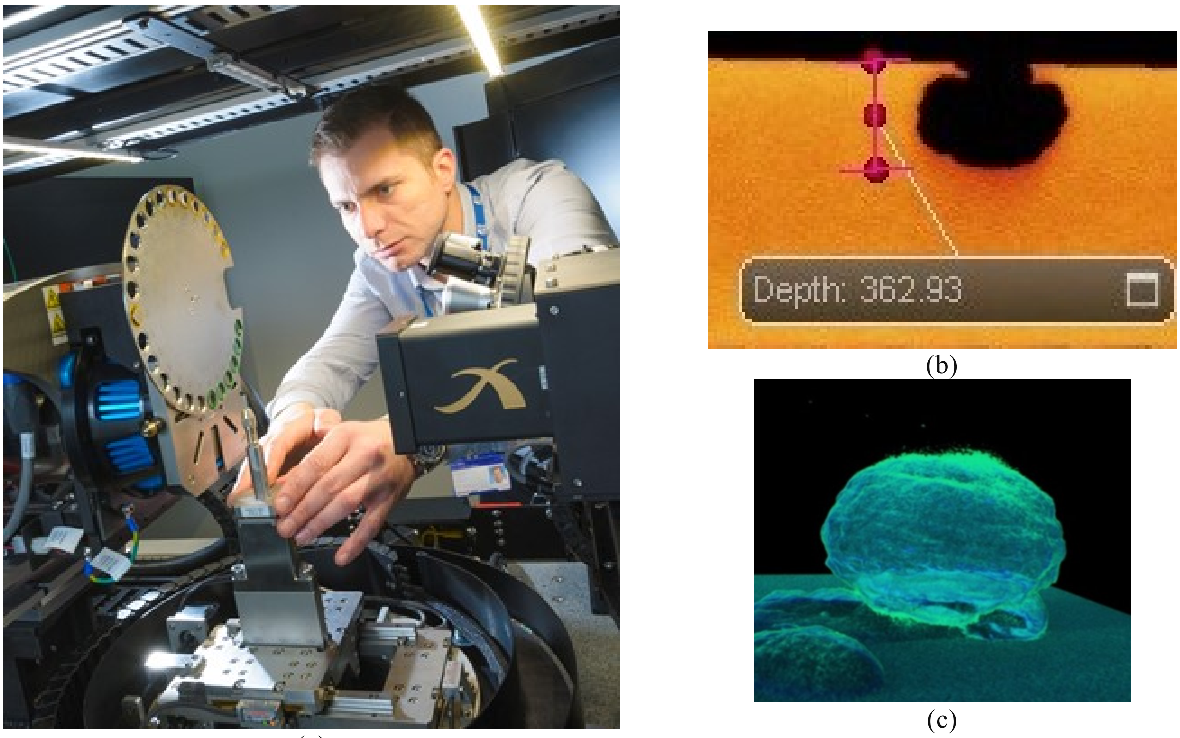

(b)

(c)

(a)

Figure 1: (a) Xradia 520 Versa at NSIRC Ltd. (b), (c) 2D and 3D image of a corrosion pit in stainless steel 314.