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CAPACITIVE IMAGING TECHNIQUE FOR CHALLENGING NDE PROBLEMS IN OIL AND GAS INDUSTRY

Xiaokang Yin[1], Wei Li, Yuan Zhu, Guoming Chen
China University of Petroleum (East China)
Qingdao, China

ABSTRACT

Capacitive Imaging (CI) technique, which employs fringing electric field between coplanar electrodes, has demonstrated its capabilities of non-destructively detecting both surface and hidden defect in dielectric materials and characterizing conducting surface through a relatively thick insulation layer. This paper aims to provide an insight into the CI technique and demonstrate its feasibility on solving some challenging inspection problems (i.e. corrosion under insulation and composite materials /structures) in the oil and gas structures. The CI concept is explained, and the experiments to investigate the usefulness of the capacitive technique for composite materials inspection and detecting corrosion under insulation are presented.

Keywords: Capacitive Imaging, CUI, composite

1. INTRODUCTION

Non Destructive Evaluation (NDE) is an effective inspection practice used across a variety of industries to ensure efficient, safe and cost effective operations of industrial equipment and assets. Various techniques are currently available to detect flaws in the equipment used across the oil and gas industry. While traditional techniques have achieved great success, in several instances (i.e. composite materials and structure, corrosion under insulation (CUI)) novel methods are required [1-3]. While many of the techniques are very useful, some have limitations in certain circumstances. For example, ultrasound has difficulty in propagating across many layered materials, and can be highly attenuated in some composites. In radiography, the inherent radiation hazards are sometimes a problem.

The CI approach described in this paper aims to offer a possible route to overcome some of the limitations imposed by existing NDE techniques. For example, the technique works in a volume averaging manner and the scattering issue in the ultrasound method is absent. CI technique is investigated in some depth to further evaluate its capability in solving some of the challenging problems in the oil and gas industry.

2. THE CI TECHNIQUE AND CI PROBE

The CI approach uses a coplanar probe with two or more electrodes in air to produce a quasi-static electric field distribution within the material. Fig 1 shows a general purpose CI probe with two back-to-back triangular electrode. The capacitive coupling allows the technique to work on a wide variety of material properties, ranging from insulators to metallic conductors. Scanning the electrodes over the material can form an image according to the changes in the output voltage from the coplanar CI probe [4]. Depending on the applications, the geometry of the electrode can be changed in to concentric or interdigital. The PCB can also be made flexible for curved surfaces.

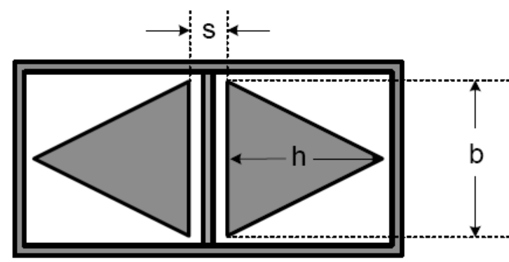

FIGURE 1: CI PROBE WITH TRIANGULAR ELECTRODES

3. CI FOR CORROSION UNDER INSULATION (CUI)

While insulated structures does protect them from temperature extremes and corrosion, it also makes it hard to do inspection [5]. As CI technique is sensitive to both defect inside the insulation layer and on the conducting surface, it can be used

[1] Contact author: xiaokang.yin@upc.edu.cn

to detect CUI. Also, it can find defects within the insulation, i.e. air void and water intrusion, before CUI could happen. CI scans were taken from an insulated metal specimen (2 mm plastic insulation above a steel plate) with artificial defects (flat bottomed holes) that simulate CUI and air void in insulation, as shown in Fig. 2. Both defect in the insulation foam and on the steel surface were detected. Metal loss (to simulate corrosion) appeared as a brighter area in the centre of the image, while air voids appears two darker areas on each side. The two type of defects showed different variation trend in the capacitive image, leading to the possibility of defect identification.

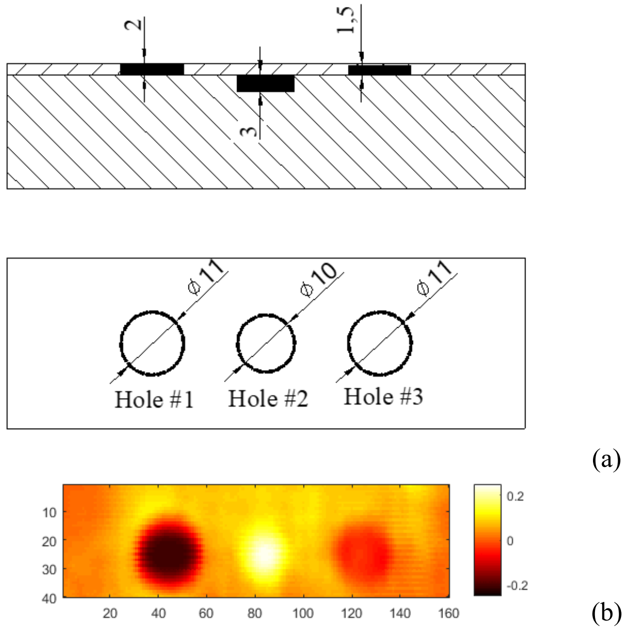

FIGURE 2: (a) SCHEMATIC DIAGRAM OF SPECIMEN WITH DEFECTS IN INSULATION LAYER AND ON METAL SURFACE AND (b) ITS CAPACITIVE IMAGE

4. CI FOR COMPOSITE MATERIALS/STRUCTURES

Composites are used in increasing range of applications in oil and gas industry. Detecting defects in composite materials has always posed something of a challenge to traditional NDT techniques [6, 7]. Being predominantly non-conducting or have relatively low conductivity, these materials cannot be tested by conventional electromagnetic methods such as eddy current (EC) testing and magnetic particle inspection. Due to their inhomogeneous and anisotropic structure, ultrasound sometimes has signal attenuation and scattering issues.

CI scans were taken from a glass fibre composite plat with artificial defects (flat bottomed holes), as shown in Fig. 3. All the holes were imaged, with the intensity corresponding to the depths of the holes..

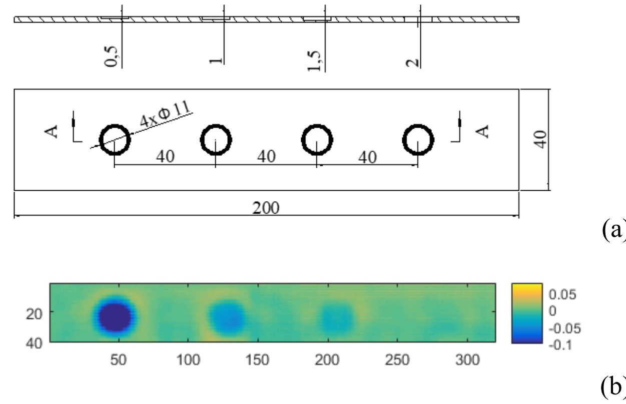

FIGURE 3: (a) SCHEMATIC DIAGRAM OF GLASS FIBRE COMPOSITE SPECIMEN AND (b) ITS CAPACITIVE IMAGE

CI scans were also taken on epoxy resin-carbon composite sucker rod. The composite sucker rod is with a carbon core and epoxy resin surface layer, as shown in Fig. 4. A curved CI probe was made to fit the surface of the sucker rod.

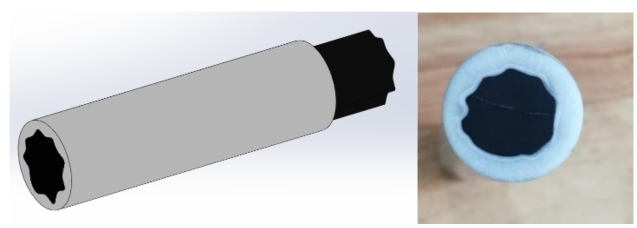

FIGURE 4: STRUCTURE OF COMPOSITE SUCKER ROD

Both the wearing defect on the epoxy resin layer and the profile of the carbon core can be obtained from CI scans, as shown in Fig. 5

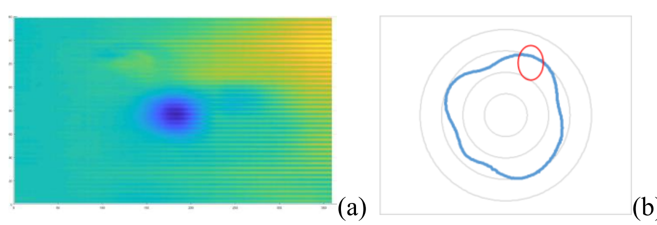

FIGURE 5: CAPACITIVE IMAGE OF (a) WEARING ON THE EPOXY RESIN LAYER AND (b) PROFILE OF THE CARBON CORE OF THE ROD

The feasibility of CI technique on the evaluation of aging status of such sucker rod was also explored. A sucker rod was placed in a high temperature and pressure chamber to simulate the downhole environment. CI measurements taken from a given sucker rod at different aging stage. The CI readings were significantly different due to moisture content variation and material dielectric constant change caused by the accelerated aging.

Field tests on a ten years old Fiberglass storage tank were also carried out. Different readings of CI probe from the south facing wall and north facing wall indicate a different aging rates of the two side due to different UV exposure.

4. CONCLUSION

The CI technique is a low cost, easy-to-implement NDE technique. It only required single side access to the specimen and provide visual indications of the targeted features. It work on a wide range of materials. Experimental results show that the CI technique is promising to solve the challenging NDE problems, i.e. CUI and composite materials /structures, in the oil and gas structures.

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