X-Ray Non-Destructive Testing Example Application: Inspection of High Voltage Cables

Introduction

Researchers The University of Southampton, with financial support from National Grid Transco, have developed an X-ray imaging technique that allows non-destructive investigation of high voltage cable joints. Defects such as thinning of the semiconducting sheaths, or of the bulk insulation, can be accidentally introduced into the cable joints during manufacture and X-ray imaging allows their inspection. The interfaces between the respective insulation components can be found by differentiating the X-ray image surface profile, which in turn allows the measurement of the thickness of each insulation component. The recorded thicknesses can then be used as a quality measure for a given high voltage cable joint.

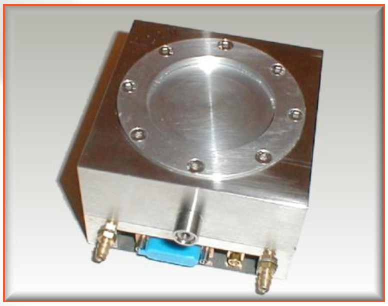

Figure 1 The CCD camera head housing a CCD bonded to a scintillating fibre optic plate (SFO) with a 1:1 ratio, supplied by XCAM Ltd.

Non-destructive cable inspection

Only cables of finite length are manufactured due to transport restrictions, requiring longer cables to be produced by joining sections of cable together. The joining of two cables is a manual procedure, requiring a non-destructive testing method to determine if any defects have been created that could reduce the working lifetime of the cable. One method of looking for joint defects is to use X-rays and photographic film, a process that suffers from problems associated with film processing and storage. These problems can be removed by replacing the photographic plate with a charge coupled device (CCD) coupled to a scintillating screen. Using a microfocus X-ray source and an X-ray CCD camera supplied by XCAM Ltd (Figure 1), digital images of small sections of cable, down to feature sizes of 20 µm, could be made. The CCD has 2048 × 2048 13 µm pixels and is connected to a scintillating fibre optic plate providing a 27.6 × 27.6 mm field of view, and X-ray efficiency up to 200 keV.

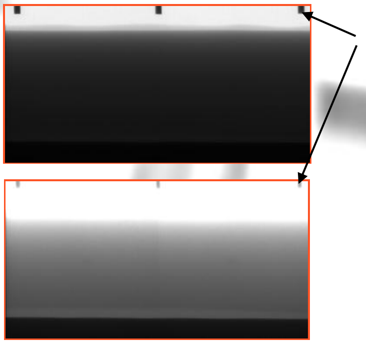

Figure 2 Two montaged CCD images of the studied cable joint using a different contrast setting in each case to highlight the various layers in the cable

Image capture and analysis

A CCD image of the sample joint was accumulated during 90 second X-ray exposures, the median pixel intensity of 10 images being used to obtain the final image for analysis. Tungsten needle markers positioned just above the surface of the cable allowed montaging of several images along the length of the cable (Figure 2). Differentiating the pixel intensity profile of each column in the image allows the position of the various interfaces to be found: air/outer semiconducting sheath (A/IS), outer semiconducting sheath/insulation (IS/I), insulation/inner semiconducting sheath (I/CS), inner semiconducting sheath/conductor (CS/C). The minimum, maximum and average thickness of each layer can then be calculated. Every interface point is then stored in a binary image which can be superimposed onto the original image of the cable joint to clearly show the interface lines (Figure 3).

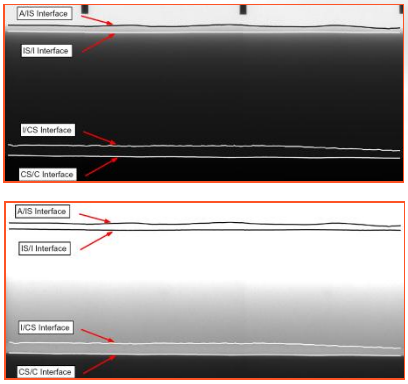

Figure 3 Two montaged CCD images, using different contrast settings, of the studied cable joint combined with the binary interface image. The different layers in the cable are labelled for clarity

Future developments

The X-ray imaging and processing technique developed has shown that non-destructive imaging of high voltage cable joints is possible using a CCD imaging detector. The boundaries of the various layers in the cable were clearly resolved and measured layer thicknesses were obtained providing data that can be used as a quantitative assessment of cable joint quality. Development of the process to provide 3D imaging capability is also under investigation. The principle involves imaging the sample cable from a number of angles and then plotting the interface points in 3D space, interpolating additional points before the final solid object is rendered. An example 3D reconstruction of a cable joint is shown in Figure 4. Further information about the CCD used for this work can be obtained from XCAM.

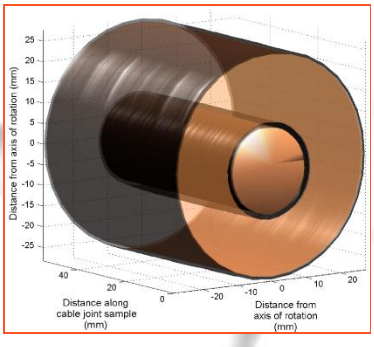

Figure 4 A reconstructed 3D image of a cable joint, produced by digital image processing of several montaged CCD images

XCAM Limited, 2 Stone Circle Road, Round Spinney, Northampton NN3 8RF

Tel: 44 (0)1604 673700, Fax: 44 (0)1604 671584
Web: www.XCAM.co.uk, Email: info@XCAM.co.uk

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