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

Application Note

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), supplied by Xcam Ltd.

Non-destructive cable inspection

- High voltage cable manufacture is an automated process. However, 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, and requires a non-destructive testing method to determine if any defects have been created that could reduce the dielectric properties of the insulation and have a detrimental effect on the working lifetime of the cable.
- One method of non-destructively looking for joint defects is to use X-rays and photographic film. This process however, suffers from problems associated with processing and storage of the film; problems that can be removed by replacing the photographic plate with a charge coupled device (CCD) coupled to a scintillating screen.
- The work carried out by the University of Southampton has used an X-Tex microfocus X-ray source to generate X-rays and an X-ray CCD camera supplied by Xcam Ltd and shown in Figure 1. The CCD has 2048 × 2048 13 μm pixels and is connected to a scintillating fibre optic plate with a 1:1 ratio providing a 27.6 × 27.6 mm field of view, and X-ray efficiency up to 200 keV. The CCD made it possible to produce digital images of small sections of the cable down to feature sizes of 20 μm, with relatively low noise.

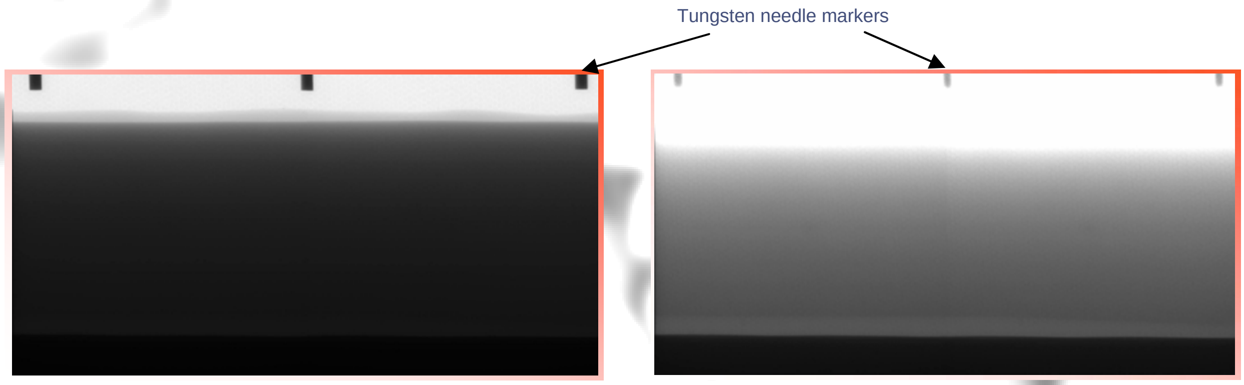

Figure 2 Two montaged CCD images of the studied cable joint using a different contrast setting in each case to highlight the various layers in the cable

Image capture and analysis

- The joint used for inspection was a section of 90 kV submarine cable. A CCD image of the joint was accumulated during 90 second X-ray exposures, the median pixel intensity of 10 such images being used to obtain the final image for analysis.

- The small CCD field of view required the cable joint to be imaged in 27 mm sections along its length. Tungsten needle markers were positioned just above the surface of the cable in regular intervals to allow montaging of several images. Figure 2 shows a final montaged image of the cable joint.

- Taking vertical sections through the cable joint image reveals the change in measured pixel intensity through the different layers in the cable. Differentiating these intensity profiles for 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, providing a qualitative assessment of the cable joint.

- Every interface point is then stored in a binary image of the cable joint which can be superimposed onto the original image of the cable joint to clearly show the interface lines. Figure 3 shows a montaged CCD image of the cable joint, combined with the binary interface image. All four interfaces were found and are labelled in the figure.

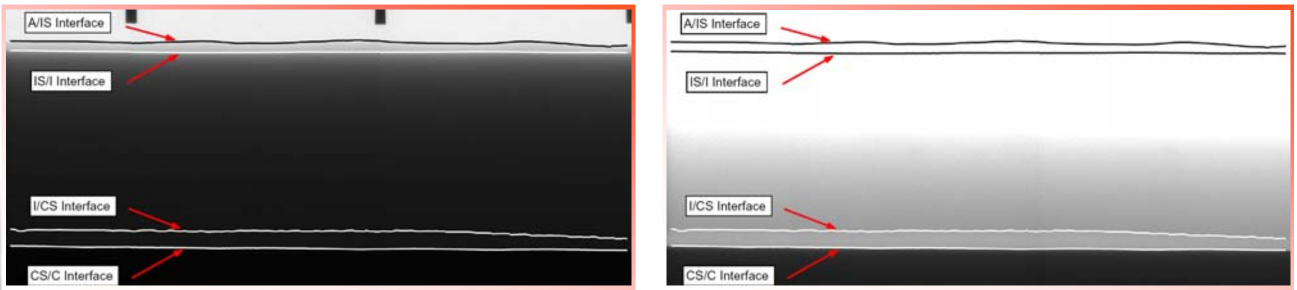

Figure 3 Two montaged CCD images, using different contrast settings, of the studied cable joint combined with the binary interface image. The different layers in the cable are labelled for clarity

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.

Further information about the CCD used for this work can be obtained from Xcam.

A more detailed version of this application note can be downloaded from the Xcam website, http://www.xcam.co.uk/notes/index.html

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